Popular Astronomy.

Vol. XV, No. 9. NOVEMBER, 1907. Whole No. 149

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M. LOEWY.
[Director of the Paris Observatory.]

The present generation of French astronomers, so cruelly depleted in the past few years, has just been plunged again into profound grief by the loss of one of its most loved and esteemed representatives. M. Trépied, director of the observatory of Algiers, while still in the prime of life was stricken down most unexpectedly on the evening of Monday, June 10, 1907; it was but a few days after he had taken a most active part in the congress of solar studies which met at the observatory of Meudon.

The high qualities of mind and heart, the constant genialness of his character had won for him the sympathies of all who had had occasion to come in contact with him, the warm friendship of all who had had the privilege of living in intimate relations with him.

M. Trépied had received a veritable calling toward astronomy. In order to give himself up to the study of this science he renounced a university career and entered the observatory of Montsouris as a voluntary observer.

Appointed in 1877 assistant member of the Bureau of Longitudes, Trépied took part in this capacity, in the editing of the *Connaissance des Temps* until 1888, when he was appointed honorary assistant member.

At the end of the year 1888 Trépied received the commission of organizing the astronomical observatory of Algiers. During the period of the temporary installation of this establishment, from 1881 to 1885, this astronomer, with the help of a single assistant, made more than 20,000 meridian observations and a great number of equatorial observations of planets and comets. He gave himself up also to research in solar spectroscopy and obtained besides about a thousand photographs of the Sun. The construction of the permanent observatory, began in 1885, was finished in 1890.

* Translated by Miss Isabella Watson of Carleton College, Northfield, Minn.

This scholar also made himself known through a very useful memoir of geodesy containing the development, to terms of the fourth order inclusive, of the formulas which express the differences of longitude, of latitude and of azimuth at the two extremities of a geodetic line. This research completes the fine work of Legendre on the analysis of the triangles at the surface of the spheroid. A numerical application of the new formulas, given in the *Comptes rendus de l'Académie des Sciences*, enables us to appreciate within what limits the developments of Legendre would be applicable if the geodesists wished to use great triangles like those with which General Perrier has affected the joining of Spain with Algiers. In 1876 Trépied published an elegant study on the photometry of the stars. This research carried on by the aid of the photometer of Arago, had a double purpose: to measure the luminous intensity of the stars and the study of the transparency of the air. He was enabled to consider all the conditions of the problem which are: 1, the difference in altitude of the stars; 2, the transparency of the air; 3, the brightness of the sky.

This memoir includes an exposition of the photometric method of Arago made complete by the introduction of terms which enable us to appreciate the effect of the transparency of the air. Starting with the differential expression of extinction given by Laplace in the *Mécanique céleste*, Trépied has succeeded in discarding all hypotheses on the height of the atmosphere, and the formulas of reduction which are here presented are new. The memoir contains also the photometric observations made by Trépied.

This astronomer also engaged in an interesting study on the method of Cauchy for the development of the perturbative function. The method in question of easy application in ordinary cases, may lead to the introduction of imaginary symbols for the comets whose eccentricity and inclination are considerable. This is notably the case for Faye's comet. The result is a difficulty in the numerical execution of the work. Trépied shows how this inconvenience can be avoided by the use of another system of auxiliary unknowns.

In collaboration with M. Thomas he published a paper on the application of high temperatures in the observation of the spectrum of hydrogen. While engaged in research on some points on solar physics Messrs. Trépied and Thomas were led to examine whether one could not observe the spectrum of hydrogen by making this gas luminous otherwise than by the electric dis-

charges into the Plücker tubes. It was found from this research that the electric arc furnishes a sure and comparatively easy means of rendering the hydrogen sufficiently luminous for spectroscopic observation, even with the use of great dispersions.

In the years 1887, 1889, 1891, 1896 and 1900 Trépied, in the position of secretary, took part in the work of the international conferences which met in the Paris Observatory for the purpose of studying questions relative to the preparation of a map of the heavens by photographic processes. The other studies which he pursued at the observatory of Algiers on astronomical photography, and whose results have been published in the *Bulletin du Comité permanent de la Carte du Ciel*, have contributed to the solution of the fundamental questions which it was necessary to investigate and solve before entering in a definitive way into this immense exploration. Trépied is one of the astronomers who have contributed the most to this great international enterprise.

The Algiers Observatory is one of the astronomical establishments which is taking part in this vast work. Trépied has there directed and personally executed all the researches accomplished in this line and his participation has been one of the most fruitful. More than 290 sheets of the map of the heavens are already published and, in the first volume of the photographic catalogue of the zone assigned to the Observatory at Algiers, Trépied has explained the methods used for obtaining the exact position of the stars photographed; this is by the aid of measures obtained on the plates.

I ought also to mention an important work published by Trépied on the occultation of the stars by the Moon; this work has the purpose of facilitating the preparatory calculations concerning the prediction of the occultations in a given place. Among the various methods which astronomy furnishes to sailors and explorers for determining the longitude of a place, one of the most direct, most rapid and most exact, consists in observing the local time of the disappearance or of the reappearance of a known star at one edge of the Moon. It is for this reason that the *Connaissance des Temps*, like the other national astronomical almanacs, gives for different dates of each year numerical elements of occultations relative to a certain number of stars. These elements make known at a definite moment the point where the center of the Moon is projected on a plane called *fundamental* which passes through the center of the Earth and which is perpendicular to the straight line from this center to the star. But the practical solution of the problem demands that,

besides the lunar elements furnished by the astronomical almanac, one should know the point where the place of observation is projected on the fundamental plane. Trépied obtains this result by means of tables or charts of extremely convenient use and which reduce the preparatory work to the greatest possible simplicity. Besides he treats in a very complete manner all the questions relative to the influences from various sources which may affect the value of a longitude determined by the method of occultations.

In various other domains of practical astronomy Trépied has given proof of a fruitful personal productivity; he has published in the *Comptes rendus de l'Académie des Sciences* or the *Bulletin astronomique*, a considerable number of notes and several papers on the most varied problems and which it would take too long to enumerate here. Finally this scholar has had the great credit of entirely creating the Observatory in Algiers and of giving to it a great development which does honor to astronomy; he has thus erected for himself a monument which will perpetuate his memory and his name will remain inscribed among those of the best servants of science.

From BULLETIN ASTRONOMIQUE, August 1907.

THE MILLS EXPEDITION FROM LICK OBSERVATORY.

W. W. PAYNE.

FOR POPULAR ASTRONOMY.

From time to time we have given brief notices of the organization and plans of the D. O. Mills Expedition from Lick Observatory to South America for the purpose of observation to complete some work already begun at the Lick Observatory.

From parts 1, 2 and 3 of Vol. IX of the University of California Publications, we learn some facts about this important expedition that will be of general interest to our readers.

Several years ago W. W. Campbell Director of the Lick Observatory, while planning his large Mills spectrograph was impressed with the need of radial-velocity observations of stars in the southern heavens as well as those in the northern heavens, in order to study the motion of the solar system through space; so to make safe progress in the study of the structure of the sidereal universe, the greatest theme of all in the natural world to occupy the human mind. Professor Campbell is right in thinking that no satisfactory solution of either of these two great astronomical problems is probable if the motions of the

stars of one-half or two-thirds of the sky only are used, no matter how completely the work in such sections may be done. On the other hand if the motions of many stars, large and small, in all parts of the sky may be determined by the aid of the spectroscope adapted to this kind of work, it is strongly probable that our knowledge in this field of astronomy will be greatly improved, even if the foundation of a working hypothesis is not laid for a measure of the size of the stellar universe itself.

This notable problem of telling us how big this great star-cluster is in which our Sun and his family of planets are but as a few grains of sand, is a most worthy one to seize upon the

OBSERVATORY OF THE D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISHHERE.

attention of Professor Campbell, and to make him very anxious to do what he can with his very unusual facilities to advance knowledge about it. It is the great question that has claimed the thinking power of the ablest minds from the time of Herschel to the present.

Director Campbell is very fortunate in having behind his planning and its execution so able, intelligent and generous a man as D. O. Mills. It will certainly be of interest to all our readers to know what this kind of benevolence means to a man when he undertakes to carry through an enterprise of this kind. We are glad to be able to give the figures though it is not usual to publish the cost of astronomical expeditions. In this case Mr. Mills

paid the sum of $26,075 for instruments, traveling expenses, supplies, insurance, salaries of astronomers, and buildings at the observing station.

The instrument used in this stellar work in Chile was a reflecting telescope. Its mirror is 36¼ inches in diameter, of the Cassegrain form. It will be remembered that to have this form of mounting the great mirror must have a hole in the center of it to bring the image of a heavenly body to the eyepiece as is usually done in the refracting telescope. The cost of this $36\frac{9}{16}$-inch reflecting telescope was $5,500 in California, only about one-eighteenth as much as the great 36-inch refractor of Lick Ob-

CERRO SAN CRISTÓBAL, SANTIAGO DE CHILE.

servatory originally cost. Professor Campbell says: "I do not doubt that in the same or equally good locations, and with good silver coats on the mirrors, the two instruments would be almost equally efficient in radial-velocity determinations. Necessarily this was the most important factor in making my decision to employ a reflecting telescope. The cost of the dome, walls and moving floor for the 36-inch refractor of the Lick Observatory exceeded the cost of the dome including its subsequent iron covering, and accessories for the $36\frac{9}{16}$-inch reflector more than twenty fold, though it should be said that the structure supporting the Chile dome is on a very modest scale."

It will be of interest to our readers also to know that work of the kind described in this brief notice is to be continued by the

aid of Mr. Mills for five years longer in the southern hemisphere. This is very desirable because of the continuity of the work under the same management and with efficient instruments.

We give herewith some illustrations of the observing station, the Observatory and a chart showing the part of the sky observed, and also an account of work done during the two years now completed in the words of the report.

"The working period of two years terminated in October, 1905. Dr. Palmer returned in September, 1905, and Professor Wright working alone thereafter made a reduced number of observations until the middle of February, 1906, when his successor arrived.

'The spectra* of all the brighter stars south of declination —25° were photographed, and on the basis of the observations thus secured, a working list of 145 stars was made up. This list includes all the stars whose spectra were found to contain measurable lines. Four spectrograms were obtained of practically every star on the list, and additional ones of many other stars were taken for special purposes. The total number of spectrograms secured by the expedition is 800, of which 676 are of stars on the regular list, 92 are of stars whose spectra were found to be unsuitable for accurate measurement, and the remaining 32 are check plates of *Mars*, *Venus*, and the Moon.

'A number of stars were found by Messrs. Wright and Palmer to have variable velocities,—in other words, they were proven to be attended by massive invisible companions. Twenty-two of these binary systems have been announced in the Lick Observatory Bulletins. One case discovered by Mr. Wright is of special interest, as it relates to the first-magnitude star *Antares*. Its variable velocity was detected by a comparison of Mills spectrograms secured in Chile with Mills spectrograms of the same star secured earlier on Mount Hamilton.

'The work of the expedition was so arranged by Mr. Wright that a majority of the spectra were photographed by him, while most of the measuring and reducing was done by Dr. Palmer. Two hundred and fifty of the spectrograms were definitely measured and reduced in Chile by Dr. Palmer and forty by Mr. Wright.

'Fifty additional plates were measured and reduced at Mount Hamilton by Dr. R. H. Curtiss in the spring of 1905, and 110 in the spring of 1906 by Dr. Palmer,—both these gentlemen being Mills' Assistants. The measurement of the remainder of the spectrograms was begun on Mount Hamilton on July 1, 1906,

* Excerpt from Report of the Director of the Lick Observatory to the President of the University for 1904-06.

by Mr. Wright and by Dr. Albrecht, Mills' Assistant. All should be completed by July of the present year.'

In the following pages Mr. Wright gives a valuable account of the activities and experiences of the expedition, with special reference to the working of the instrumental equipment. The subjects discussed are in general those which promise to be useful to other observers engaged in closely related lines of work,

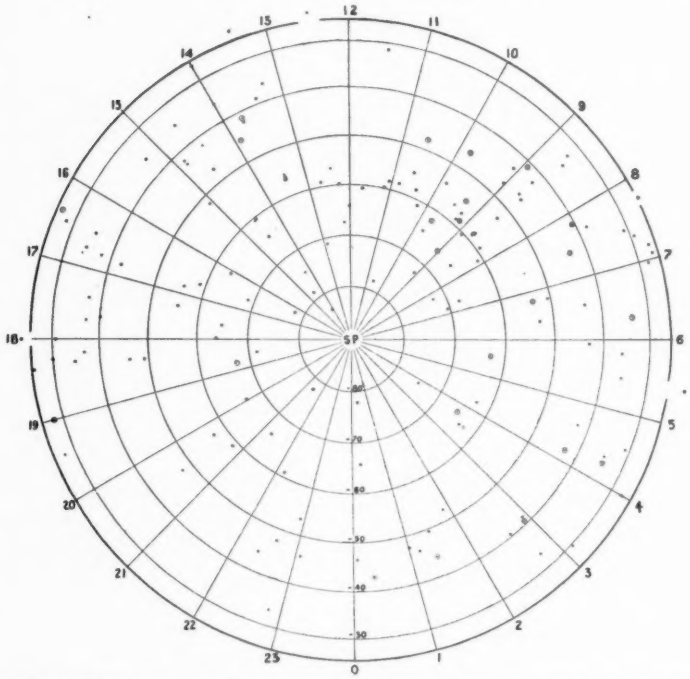

CHART SHOWING THE DISTRIBUTION OF STARS OBSERVED BY THE MILLS EXPEDITION. The method of projection is such that equal areas on the chart represent equal areas in the sky. Encircled stars have variable radial velocities.

including alike those which were entirely satisfactory and those which were capable of further improvement. In reading this account, two facts should be held in mind:

1.—The expeditionary character of the organization. In forming the general plans and in designing the instrumental equipment, I had no thought other than that the work of the expedition would terminate at the end of two years of actual observation,

and the instruments be dismounted and returned to this country. The more massive parts of the telescope mounting were kept as light as possible, with a view to their transport to the summit of a hill or mountain that might or might not have a road. Nothing was planned for in the equipment which was not needed in line-of-sight determinations. The requirements of other lines of investigation,—general astronomical photography, for example,—were given no consideration. The dome was covered with heavy canvas (painted) instead of metal, and similarly in other cases.

2.—The successful measurement of stellar radial velocities has been shown by wide experience to be one of the most difficult problems in modern observational astronomy. I had expected that this, the first serious attempt to measure stellar velocities with a large Cassegrain reflecting telescope, involving many radical departures from conventional forms, would develop its own crop of difficulties, to be removed one by one. For this reason, all parts of the telescope were hauled to the summit of Mount Hamilton, and the telescope and spectrograph were completely assembled, preparatory to securing successful spectrograms here, and to permit the discovery and removal of the anticipated defects and difficulties. This plan was imperatively abandoned. The first assembling and testing of the completed apparatus occurred on the summit of a mountain in Chile, away from instrument makers and machine shops, and it was a great relief to learn that no vital difficulties were encountered. Minor ones there were, but perhaps fewer than anticipated. In fact, no changes of any consequence were made in the instrumental equipment or methods, save by way of temporary experiments.

In the erection of the observatory on *Cerro San Cristóbal* during the rainy season, in meeting and overcoming difficulties as they arose, and in carrying out the program of observation as planned, within the estimated time,* Acting Astronomer William H. Wright, in charge of the expedition, is entitled to great credit. Most important of all, the accuracy of the observations appears to equal that of the observations made with the Mills spectrograph at Mount Hamilton. Notwithstanding many unexpected and extraordinary expenses in securing the mirrors for the telescope, the expenditures were within the originally estimated sum."

* It should be noted that the first year of observation, ending October 31, 1904, was abnormally cloudy, only one year in the preceding forty-three years having had a greater number of cloudy days, according to the records of the Chilean National Observatory, in Santiago.

EXTRACTS FROM PRESIDENTIAL ADDRESS, II.*

SIR DAVID GILL.

The Distribution of Varieties of Luminosity of Stars.

But besides the mean parallax of stars of a particular magnitude and proper motion, it is essential that we should know approximately what percentage of the stars of such a group have twice, three times, etc., the mean parallax of the group, and what percentage only one-half, one-third of that parallax, and so on. In principle, at least, this frequency-law may be obtained by means of the directly determined parallaxes. For the stars of which we have reliable determinations we can compare these true parallaxes with the *mean* parallax of the stars having corresponding magnitude and proper motion, and this comparison will lead to a knowledge of the frequency-law required. It is true that, owing to the scarcity of material at present available, the determination of the frequency-law is not so strong as may be desirable, but further improvement is simply a question of time and the augmentation of parallax determination.

Adopting provisionally the frequency-law found in this way by Kapteyn,† we can localize all the stars in space down to about the ninth magnitude.

Take, for example, the stars of magnitude 5.5 to 6.5. There are about 4800 of these stars in the whole sky. According to Auwers-Bradley, about 9½ per cent of these stars, or some 460 in all, have proper motions between 0″.04 and 0″.05. Now, according to Kapteyn's empiric formula, whose satisfactory agreement with the Yale results has just been shown, the mean parallax of such stars is almost exactly 0″.1. Further, according to his frequency-law, 29 per cent of the stars have parallaxes between the *mean* value and double the mean value; 6 per cent have parallaxes between twice and three times the mean value; 1½ per cent between three and four times the mean value. Therefore, of our 460 stars 133 will have parallaxes between 0″.01 and 0″.02, 28 between 0″.02 and 0″.03, 7 between 0″.03 and 0″.04, and so on.

Localizing in the same way the stars of the sixth magnitude having other proper motions, and then treating the stars of the

* Delivered at the meeting of the British Association, July 31, 1907.

† Publications Astron. Lab. Groningen, No. 8, p. 23.

first magnitude, second magnitude, third magnitude and so on to the ninth magnitude in the same way, we finally locate all these stars in space.*

It is true we have not localized the individual stars, but we know approximately and within certain limits of magnitude the number of stars at each distance from the Sun.

Thus the apparent brightness and the distance being known we have the means of determining the light-energy or absolute *luminosity* of the stars, *provided it can be assumed that light does not suffer any extinction in its passage through interstellar space.*

Consider, lastly, the distribution of stellar density, that is, the number of stars contained in the unit of volume.

We cannot determine *absolute* star-density, because, for example, some of the stars which we know from their measured parallaxes to be comparatively near to us are in themselves so little luminous that if removed to even a few light-years greater distance they would appear fainter than the ninth magnitude, and so fall below the magnitude at which our data at present stop.

But if we assume that intrinsically faint and bright stars are distributed in the same proportion in space, it will be evident that the comparative richness of stars in any part of the system will be the same as the comparative richness of the same part of the system in stars of a particular luminosity: Therefore, as we have already found the arrangement in space of the stars of different degrees of luminosity, and consequently their number at different distances from the Sun, we must also be able to determine their relative density for these different distances.

Kapteyn finds in this way that starting from the Sun, the star-density (*i. e.* the number of stars per unit volume of space) is pretty constant till we reach a distance of some 200 light-years. Thence the density gradually diminishes till, at about 2500 light-years, it is only about *one-fifth* of the density in the neighborhood of the Sun.† This conclusion must, however, be regarded as uncertain until we have by independent means been enabled to estimate the absorption of light in its course through interstellar space, and obtained proof that the ratio of intrinsically faint to bright stars is constant throughout the universe.

Thus far Kapteyn's researches deal with the stellar universe as

* Publications Astron. Lab. Groningen, No. 11, Table II.

† *Ibid.* No. 11.

a whole; the results, therefore, represent only the *mean* conditions of the system. The further development of our knowledge demands a like study applied to the several portions of the universe separately. This will require much more extensive material than we at present possess.

As a first further approximation the investigation will have to be applied separately to the Milky Way and the parts of the sky of higher galactic latitude. The velocity and direction of the Sun's motion in space may certainly be treated as constants for many centuries to come, and these constants may be separately determined from groups of stars of various regions, various magnitudes, various proper motions, and various spectral types. If these constants as thus separately determined are different, the differences which are not attributable to errors of observation must be due to a common velocity or direction of motion of the group or class of star to which the Sun's velocity or direction is referred. Thus, for example, the Sun's velocity as determined by spectroscopic observations of motion in the line of sight appears to be sensibly smaller than that derived from fainter stars. The explanation appears to be that certain of the brighter stars form part of a cluster or group of which the Sun is a member, and these stars tend to some extent to travel together. For these researches the existing material, especially that of the determination of velocities in the line of sight, is far too scanty.

Kapteyn has found that stars whose proper motions exceed 0″.05 are not more numerous in the Milky Way than in other parts of the sky;* in other words, if only the stars having proper motions of 0″.05 or upwards were mapped there would be no aggregation of stars showing the existence of a Milky Way.

The proper motions of stars of the second spectral type are, as a rule, considerably larger than those of the first type; but Kapteyn comes to the conclusion that this difference does not mean real difference of velocity, but only that the second-type stars have a smaller luminosity, the mean difference between the two types amounting to 2½ magnitudes.†

But for the solution of the riddle of the universe much more is required. Besides the proper motions, which would be derived from the data just described, we need for an ideal solution to know the velocity in the line of sight, the parallax, the magnitude, and the spectrum-type of every star.

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* Verl. Kn. Akad. Amsterdam, January 1893.

† *Ibid.* April 1892.

The broad distinction between these latter data and the determination of proper motion is this, that whereas the observations for proper motion increase in value as the square of their age, those for velocity in the line of sight, parallax, magnitude, and type of spectrum may, for the broader purposes of cosmical research, be made at any time without loss of value. We should therefore be most careful not to sacrifice the interests of the future by immediate neglect of the former for the latter lines of research. The point is that those observatories which undertake this meridian work should set about it with the least possible delay, and prosecute the program to the end with all possible zeal. Three observatories in each hemisphere should be sufficient; the quality of the work should be of the best, and quality should not be sacrificed for speed of work.

But the sole prosecution of routine labor, however high the ultimate object, would hardly be a healthy condition for the astronomy of the immediate future. The sense of progress is essential to healthy growth, the desire to know must in some measure be gratified. We have to test the work that we have done in order to be sure that we are working on the right lines, and new facts, new discoveries, are the best incentives to work.

For these reasons Kapteyn, in consultation with his colleagues in different parts of the world, has proposed a scheme of research which is designed to afford within a comparatively limited time a great augmentation of our knowledge. The principle on which his program is based is that adequate data as to the proper motions, parallaxes, magnitudes, and the type of spectrum of stars situated in limited but symmetrically distributed areas of the sky, will suffice to determine many of the broader facts of the constitution of the universe. His proposals and methods are known to astronomers and need not therefore be here repeated. In all respects save one of these proposals are practical and adequate, and the required coöperation may be said to be practical and adequate, and the required coöperation may be said to be already secured—the exception is that of the determination of motion in the line of sight.

All present experience goes to show that there is no known, satisfactory method of determining radial velocity of stars by wholesale methods, but that such velocities must be determined star by star. For the fainter stars huge telescopes and spectroscopes of comparatively low dispersion must be employed. On this account there is great need in both hemispheres of a huge reflecting telescope—six to eight feet in aperture—devoted almost

exclusively to this research. Such a telescope is already in preparation at Mount Wilson, in America, for use in the northern hemisphere. Let us hope that Professor Pickering's appeal for a large reflector to be mounted in the southern hemisphere will meet with an adequate response, and that it will be devoted there to this all-important work.

Conclusion.

The ancient philosophers were confident in the adequacy of their intellectual powers alone to determine the laws of human thought and regulate the actions of their fellow men, and they did not hesitate to employ the same unsupported means for the solution of the riddle of the universe. Every school of philosophy was agreed that some object which they could see was a fixed center of the universe, and the battle was fought as to what that center was. The absence of facts, their entire ignorance of methods of exact measurement, did not daunt them, and the question furnished them a subject of dispute and fruitless occupation for twenty-five centuries.

But astronomers now recognize that Bradley's meridian observations at Greenwich, made only 150 years ago, have contributed more to the advancement of sidereal astronomy than all the speculations of preceding centuries. They have learned the lesson that human knowledge in the slowly developing phenomena of sidereal astronomy must be content to progress by the accumulating labors of successive generations of men: that progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and that, in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work.

By these means we shall learn more and more of the wonders that surround us, and recognize our limitations when measurement and facts fail us.

Huggin's spectroscope has shown that many nebulæ are not stars at all; that many well-condensed nebulæ, as well as vast patches of nebulous light in the sky, are but inchoate masses of luminous gas. Evidence upon evidence has accumulated to show that such nebulæ consist of the matter out of which stars (*i. e.* suns) have been and are being evolved. The different types of star-spectra form such a complete and gradual sequence (from simple spectra resembling those of nebulæ onwards through

types of gradually increasing complexity) as to suggest that we have before us, written in the cryptograms of these spectra, the complete story of the evolution of suns from the inchoate nebulæ onwards to the most active Sun (like our own), and then downward to the almost heatless and invisible ball. The period during which human life has existed on our globe is probably too short—even if our first parent had begun to work—to afford observational proof of such a cycle of change in any particular star; but the fact of such evolution, with the evidence before us, can hardly be doubted. I most fully believe that, when the modifications of terrestrial spectra under sufficiently varied conditions of temperature, pressure, and environment have been further studied, this conclusion will be greatly strengthened. But in this study we must have regard also to the spectra of the stars themselves. The stars are the crucibles of the Creator. There we see matter under conditions of temperature and pressure and environment, the variety of which we cannot hope to emulate in our laboratories, and on a scale of magnitude beside which the proportion of our greatest experiment is less than that of the drop to the ocean. The spectroscopic astronomer has to thank the physicist and the chemist for the foundation of his science, but the time is coming—we almost see it now—when the astronomer will repay the debt by wide-reaching contributions to the very fundamenta of chemical science.

THE OBSERVATORY, September, 1907.

A GRAPHIC METHOD FOR LUNAR ECLIPSES.

KURT LAVES.

FOR POPULAR ASTRONOMY.

In a course of lectures on "Spherical Trigonometry with applications" the following method for graphic construction of lunar eclipses was developed. I have not seen this method mentioned anywhere and I trust it will prove to be of sufficient interest to the readers of this journal since it is rather simple and permits of a greater accuracy than the graphic method usually employed.

It consists mainly in plotting the *curve of distance* between the center of the shadow and of the Moon, with the time as independent variable. The hourly change of distances is almost uniform during the beginning and the end of an eclipse, so that these branches are very nearly straight lines. The times of enter-

ing and exit of penumbra and umbra will be obtained by measuring off as ordinates the special values of the corresponding distances. With a sufficiently large scale it is not difficult to obtain these times with an error not exceeding 0.^{m}5. For the

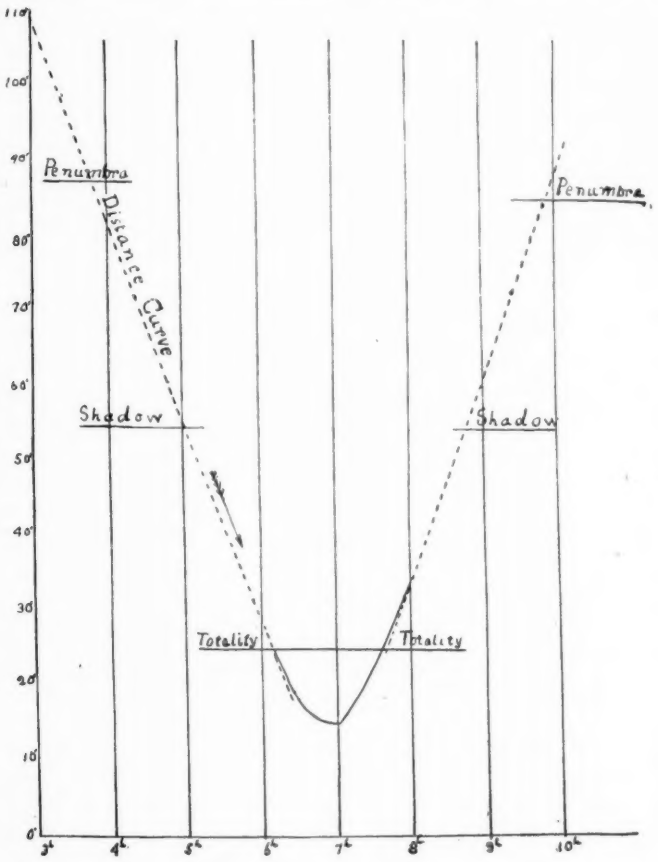


FIGURE 1. TOTAL LUNAR ECLIPSE, APRIL 22, 1907.
⊙ Original hourly points [for penumbra and shadow].
+ addition points [for duration of totality].

beginning and end of totality the straight lines referred to will quite often grant sufficient approximation, but cases will occur where it will be necessary to obtain the graph that connects the two straight lines from data which are one half hour or

even less apart from each other. The change of distance in the neighborhood of totality is frequently very sudden so that we cannot interpolate readily from the computed distances. Two eclipses have been plotted by this method; one of them is the eclipse of 1902 April 22, which is mentioned in detail in Buchanan's book on eclipses. On plate X Figure 27 of this very useful book this eclipse is plotted as it appears in the sky and on pages 207, 209, 210 the values on which the exact calculation is depending are stated in detail. Buchanan measures the hours off on the path of the Moon. By comparison with the accompanying plot it will be seen that the determination of the individual epochs in Buchanan's diagram requires the construction of two circles, which touch each other. An error in this construction

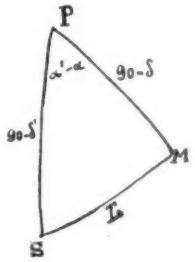


FIGURE 2.

will produce a corresponding error in the position of the center of the Moon and on that the error in the epoch is depending. In the graph of distances on the other side the individual epoch depends upon the intersection of the graph by a line parallel to the t-axis. This is a much more accurate proceeding. Moreover the penumbra changes its radius in an interval of 5 or 6 hours by an appreciable amount (in the case of eclipse in question it is 0′.1); this will require, since the same is true of the umbra, the construction of two additional concentric circles bringing in the figure the number of circles up to eleven. The danger of overloading the diagram is entirely absent in the method here proposed which we will now develop.

In the spherical triangle between the north pole of the equator the center of the Moon and the center of the shadow, the sides are L (distance between the centers), $90 - \delta$ and $90 - \delta'$ where δ and δ' are the declination of the Moon and the shadow. The angle opposite to L is $\alpha' - \alpha$ and the application of the cosine — theorem to side L gives

$$\cos L = \sin\delta \sin\delta' + \cos\delta \cos\delta' \cos(\alpha' - \alpha)$$

or

$$\cos L = \cos(\delta - \delta') - 2\cos\delta \cos\delta' \sin^2\left(\frac{\alpha' - \alpha}{2}\right)$$

or

$$\sin^2 L/_2 = \sin^2\left(\frac{\delta - \delta'}{2}\right) + \cos\delta \cos\delta' \sin^2\left(\frac{\alpha' - \alpha}{2}\right)$$

From the apparent size of the semidiameter of the Moon and the semidiameter of the shadow-circle where the Moon crosses it, it follows that neither $\alpha' - \alpha$ nor $\delta - \delta'$ will exced $2°.50$. An error of one or two seconds of arc will not be introduced into L by putting $\sin x = x.\ \sin 1''$ in the above equation. We shall therefore obtain:

$$L^2 = (\delta - \delta')^2 + \cos\delta \cos\delta' (\alpha - \alpha')^2 \qquad \text{I.}$$

When we compute L from this equation for every hour extending it for three or four hours to both sides of the middle of the eclipse we have all the material in hand to plot the L-curve.

The accompanying graph of the eclipse of April 22, 1902 will make this clear. The time of opposition in right ascension is $6^h.9$ Greenwich Mean Time. From the nautical almanac the places of the Moon and the shadow are taken and for the hours 3, 4, 5, 6, 7, 8, 9, 10, the corresponding values of L are quickly computed and on coördinate paper with properly chosen unit the seven intervals of one hour each are laid off. The endpoints of the ordinates L for the first four and the last three hours are very nearly in a straight line. We next compute the special values of L for the entering and exit of penumbra and shadow and the beginning and end of totality. In a first approximation we take a mean value of the parallax of the Moon π and compute the three values:

$L_1 = (\pi_1 + \pi' + s')\frac{51}{50} + s$	Penumbra	π_1 horiz. parallax of Moon for latitude 45
$L_2 = (\pi_1 + \pi' - s')\frac{51}{50} + s$	Umbra	π' horiz. equat. par. of Sun
$L_3 = (\pi_1 + \pi' - s')\frac{51}{50} - s$	Totality	s, s' apparent semidiameter of Moon and Sun.

In the calculation these values came out as $87'$, $54'$, $25'$ and when laid off as ordinates in our diagram we obtain the following times, which are to be considered as first approximations to the true values:

Penumbra	Entrance	3^h	49^m
	Exit	9	58
Umbra	Entrance	5	3
	Exit	8	45
Totality	Beginning	6	9
	End	7	40

Since π_1 the parallax of the Moon, varies with the time, it is necessary to know approximately the time for which the individual value of π_1 is desired. In a second approximation we employ these times and compute L_1 and L_1', L_2 and L_2', L_3 and L_3' where the index refers each time to the exit. In this way the six values of L are obtained (see Buchanan page 209). From our diagram the values of the six times come out as follows:

$3^h\,49^m$, $9^h\,57^m$, $5^h\,0^m$, $8^h\,45^m$, $6^h\,9^m$, $7^h\,39^m$.

Comparing our values with those that Buchanan has obtained by the purely analytic method we see that the first four values agree to the minutes, whilst the last two show differences the first of one and the last of four minutes (in Buchanan's value a misprint has occurred the number is $7^h\,35^s.46$ and not $3^s.546$). These deviations were to be expected, since the graph which passes through the lowest three points is quite undetermined yet. It is but necessary to compute L for $6^h\,12^m$ and $7^h\,24^m$ and $7^h\,36^m$ in order to obtain the direction of the tangent to the curve at the ordinates which belong to the beginning and end of totality. We observe that the value of L at $6^h\,12^m$ forces the direction of the curve more to the right than it would follow from the positions at 3^h, 4^h, 5^h. Similarly the branch passing through the endpoints of ordinates at $6^h\,24^m$, $6^h\,36^m$ and $6^h\,48^m$ deviates from the terminal straight line considerably to the left. The end of totality from our graph is $7^h\,35^m.5$ in close agreement with Buchanan's value.

The computation of formula I is very rapid when proper tables are used and the angular quantities are expressed in *minutes* of arc. Indeed in almost all cases we can take for $\cos\delta\cos\delta' = \cos^2\left(\frac{\delta+\delta'}{2}\right)$ so that we have obtained $\alpha' - \alpha$ in minutes of arc. We reduce it by $\cos^2\left(\frac{\delta+\delta'}{2}\right)$ (without the use of logarithms). An extended table of squares is then used to find L accurate to about $0'.1$. A sheet of coördinate paper 12×20 inches is plenty large to plot the L-curve so accurately that one minute will be represented by $\frac{3}{16}$ inch, whilst one hour of time will measure $1\frac{3}{4}$ inches. This kind of coördinate paper is used extensively at the office of the Berliner Jahrbuch and the accompanying diagram has been

drawn on a sheet 10×12 inches. It will be seen that greater accuracy can be obtained if one measures all the quantities that enter into the diagram along the two axes of the coördinate paper. This is the case in our diagram, whilst the graphic method as given in Buchanan's book introduces a third direction which deviates from these principal ones. Measurements along this line and perpendicularly to it depart from the essential advantage of the coördinate paper. Careful measurements will show that the ruling of good coördinate paper is done with a remarkable degree of accuracy. Very often we fail to avail ourselves of the improved conditions that the modern machine-made tools put before us, and it seems that the graphic methods should have a very much more prominent place in the work of our class rooms. The observation of lunar eclipses will seldom necessitate that accuracy in the numerical results which the Nautical Almanac seems to obtain. It would seem as if it would be a timely move to substitute to a larger degree diagrammatic illustrations which frequently furnish at a glance a very much better insight into a phenomenon of nature. One more remark seems not to be out of place here: If lunar tables were available which furnish the celestial latitude and longitude for every hour the formula I would be materially simplified. Indeed we would obtain

$$L^2 = \beta^2 + \cos^2 \beta . (\lambda' - \lambda)^2.$$

The "connaissance des temps" gives λ and β for the Moon for every sixth hour of the day; this interval is too large and the interpolation which would be necessary forbids its use for our present problem, otherwise it would introduce a simplification to use the ecliptical coördinates instead of the equatorial coördinates. The rate of change of L will depend upon the rate of change of β and of $\lambda' - \lambda$, but the magnitude of L will likewise play an important rôle. Indeed we have: $\cos L = \cos \beta \cos(\lambda - \lambda')$ and we obtain by differentiation:

$$\frac{dL}{dt} = \frac{\sin \beta}{\sin L} \cos (\lambda - \lambda') \frac{d\beta}{dt} + \frac{\cos \beta}{\sin L} \sin (\lambda' - \lambda) \frac{d (\lambda' - \lambda)}{dt}.$$

When the inclination of the Moon's orbit is considered to be constant—a rather close assumption which we will make here—we shall be able to express both $\frac{d\beta}{dt}$ and $\frac{d (\lambda' - \lambda)}{dt}$ in function of the absolute orbital velocity of the Moon and of the relative orbital velocity of the Moon and the Earth. It would be an entirely possible proposition to tabulate $\frac{dL}{dt}$ with respect to the

position of the Moon in its orbit and the Earth in its orbit. With $\frac{dL}{dt}$ as a varying parameter certain types of L-curves could be constructed and an individual eclipse classed accordingly. But the work involved in such a tabulation would hardly be spent to advantage and the plotting of an individual L-curve without reference to these types is preferable. In conclusion it is to be noted that practically no number is computed in the evolution of values of L, which will not be used in the more exact analytical proceeding.

The University of Chicago,
September 1907.

THE PLANET MARS.

W. W. PAYNE.

FOR POPULAR ASTRONOMY.

Some of our readers have asked what is new about the planet Mars. To such queries we could only say that nothing really new about the planet has been found out lately of which we know. For weeks past there have been rumors that the surface markings, called canals, have been photographed by the expedition sent out by Percival Lowell which has been in Chile, South America, for the purpose of observing Mars at this opposition.

By the latest news that came to hand a few days ago, it is pretty sure that the attempt to get photographs of some of these faint marks on the surface of the little fiery planet has been successful.

It is known to most of our readers, if not to all, that once in about fifteen years, the planet comes much nearer to the Earth than it does at other times. This is due to the shape of the orbits of the two planets and the way they are placed in space in regard to each other.

In 1877 this relation was true, and Professor Asaph Hall, then at the Naval Observatory, Washington, D. C., was studying the planet and looking for objects near it, to learn if such might not be satellites belonging to it. After long and patient search, he was successful in finding two tiny objects that proved to be moons to Mars. They were so small that it was not very easy then to see them in the large Washington telescope which has an object-glass of twenty-six inches in clear aperture. They were plain enough to be sure of the fact that they were moons and

not small stars, for their motions around the planet could be followed, but no idea of their exact sizes could then be gained, because they looked like very faint stars. Planets and satellites have disks and do not twinkle. Stars do not have real disks when seen in the telescope, but they do have false disks and they twinkle. The discovery of these two tiny moons was a great triumph for Professor Hall, and it was thought of as such by astronomers the world over.

In this same year, 1877, Giovanni V. Schiaparelli astronomer in Italy, was the first to find faint lines in the surface of Mars, and in speaking of them at the time he called them *canali* which means channels, an apt name for the look of them as he saw them then in his seven-inch telescope, or, as they have later appeared in many other and larger telescopes. This work of Schiaparelli aroused still more interest in the planet Mars, and since that time at each of the times of near approach to the Earth the planet has been studied by several astronomers with more or less success as their plan of work and the circumstances of it have been well chosen and favorable or not.

Those who have done best and most in this field have given close attention to drawings and to maps. Schiaparelli did his first work in that way, and he kept it up later. So also, Flammarion, W. H. Pickering and Percival Lowell; the latter in very complete way at his own observatory with his assistants, at Flagstaff, Arizona.

Schiaparelli's drawings at first were crude; in 1879, 1881 and 1882 they were better, because of the experience he had gained in keeping at the same work. He trained his eye to that one kind of work, and when he had learned where, when, and how to see the best, and so to find the most, he could surely put more of detail in his drawings and so make his general maps of the surface of Mars more complete. They are good records of early work on the ruddy planet.

After a long search for the best observing place he could find in the world, all things considered, Percival Lowell chose a site for his observatory at Flagstaff, Arizona, which is located on a plateau about 7000 feet above the level of the sea. Its elevation, its dry atmosphere, its winds and the nature of its air waves are said to be such as to make it one of the best for observation, if not the very best, known in this country.

In 1894, Mr. Lowell began observations on the planet Mars at Flagstaff, with a twenty-four inch telescope made at the shop of Alvan Clark and Sons. He has continued this work with the

help of skilled assistants until the present time. In the meantime he has published three large volumes of the work of his observatory pertaining to the planet Mars, several popular books on Mars and other science themes, besides giving many lectures and writing much for magazines in the same lines. Mr. Lowell has been a very busy man for astronomy during the last ten years and more.

Very likely many of our readers have seen the third volume of the annals of the Lowell Observatory, and if so, the most of what follows will not be new to them. It will not at all fully represent the contents of the volume. The book itself only can do that. The contents gives a full history of the observations of the planet Mars during the oppositions of 1894, 1896, 1898, 1901, and 1903. In 1894 the entire surface of the planet had been observed and a large number of drawings of fine details made which added much new matter to the knowledge of surface markings before known. The results of the work of that opposition came to us in the form of twelve large photographs, each representing one-half of the surface of the planet, but having the central meridian in itself different from that of every other. These meridians were chosen thirty degrees apart so that the set showed every part of the surface of the planet equally well. The idea was a good one, and it worked out very well. These photographs were from drawings, first made at the telescope, then transferred to a globe and finally photographed from the globe.

The question might be asked why the photographs were not made from the planet in the first place and avoid the errors of two drawings before the final photograph was reached. The answer to this query is: It had been repeatedly tried to photograph larger planets directly without success. The image of Jupiter, even, in the telescope is so small that almost all detail is lost in the attempt except that of the strong belts near the equator. Now Jupiter is more than ten times the diameter of the Earth; but Mars has a diameter only about one-half as great. Although Mars is much nearer to the Earth than Jupiter at all times, yet the sizes of the images of the two planets vary greatly when each is seen in the telescope under the most favorable circumstances. For example, the size of the image of the planet Jupiter is twice as great in diameter as that of Mars when each is as near to the Earth as it can be. More than that, the brightnesses of the two planets vary greatly; and this is a fact that the astronomer must take account of when he observes the planets visually in the telescope, or tries to get a picture of them with

the photographic camera. The astronomer calls the brightness of the planet its albedo. By that word he means the amount of sunlight that is reflected from the planet's surface to the eye of the observer. If we should call the light from the Sun that falls on the surface of Mars, 100, the sunlight that would be reflected to the eye from the surface would be only 22, while that from the planet Jupiter would be 62. This great difference due to the difference in the nature of the surfaces of the planets in the way they give up sunlight that falls on them is a matter of great interest to the student of astronomy who cares to think about it, and to the astronomer who must take notice of it in his work on the planets.

If the reader will take the pains to think of these facts as bearing on the attempt to photograph the planets directly he will realize something of the task that is in hand when even a skilled photographer makes the trial.

The advantages of the visual method are that the observer may and does get fine views of the surface of the planets at times for very brief intervals that he may draw so that they will be very nearly right. Much careful and patient work of this kind has so far proved much more satisfactory than the results of photography, for the simple reason that photographic plates must be exposed for a time so long that the good seeing and the bad are made up in one picture and of course the bad prevails and the results are unsatisfactory.

In fitting out the expedition for observing the planet Mars at this opposition Mr. Lowell has had several things in his favor. Some of the more important of these are, the choice of a good observing place in Chile, in South America, where the path of the planet would run high, almost through the zenith; on a high, arid desert, dry air which in the main was steady and very clear. In *Nature* (September 19) Mrs. Todd who is with the expedition writes: "Night after night, on the scale of five the 'seeing' was reported as four and a half while magnifying powers of six hundred were frequently used and sometimes the double of that number."

Professor Todd took with him for this work the Amherst College 18-inch refractor for visual and photographic work, although the purpose of the expedition was chiefly for photographic results. He is also provided with a photographic camera made by Wm. Gaertner & Co., of Chicago with amplifying and multiplying attachments so that 50 or 60 images on the same sensitive plate could be secured.

Mr. Slipher of the Lowell Observatory at Flagstaff, Arizona, did the photographic work. It is said in the article above referred to, that he exposed more than one hundred and fifty plates on which appear between seven and eight thousand separate images of the planet of Mars, which were taken in varying times of exposure, as is usual in that kind of photographic work. What has been spoken of already about the instants of fine "seeing" when details flash out boldly is said to appear on the same plate in these photographs wherein some images are more distant than others, and more detail is caught in some than in others.

The time of opposition for the planet Mars came on July 6, this year, but the nearest approach of the planet to the Earth did not take place until a week later, July 13. For about three weeks including this date the opportunity for the work of this expedition was almost equally good. What was accomplished during that time is plainly and well told in the words of Mrs. Todd in the article already cited, as follows:—

"One complete circumference of Mars was photographed, new areas coming into view as the nights and weeks went on. Polar snow caps, of course, appear on all the plates, the south one very large, the north conspicuous as well; the so-called 'seas' or more likely areas of desert, threaded by canals and diversified by oases, also show plainly. Photographing the canals is a great satisfaction, considering that Schiaparelli for nine years had it entirely to himself, his drawings being regarded as imaginative productions, his very announcement tacitly derided. In the worst seeing the poorest negatives show both canals and oases. But the crowning achievement of the expedition—result of astronomical and mechanical skill, fine equipment, photographic ability, steady atmosphere, and unremitting effort, in which all members of the expedition and nature itself, must each receive credit—is the appearance on the sensitive plate of several canals manifestly and undeniably *doubled*—a phenomenon visually discovered and announced by the Italian astronomer in 1882 confirmed later by Mr. Lowell and so drawn in his maps of the planet. Most conspicuous of these doubled waterways is Nilo Syrtis, and among others so shown are Nilokeras and Euphrates, and the wide double Gihon. Most difficult of all and the narrowest yet photographed is Thoth—a veritable triumph. Photographic plates, like figures, do not lie—and now for the first time these doubled markings are unmistakably impressed on negatives."

From these statements and many others like them it is probable that some very able astronomers will sometime have to change their minds who still say there is nothing in the reports of observers who see fine, long markings, in large number, on

the surface of Mars and call them canals. Too many observers are seeing some of the same objects. In the main maps made during the last twenty years by different able observers agree so well that the probability of the truth they assert is growing pretty strong. Conservative work in science is well; but when it goes too far, it is neither true in spirit nor safe in principle.

From the questions that come to us often some of our readers would like to know, doubtless, what is the latest that astronomers have to say about the canals themselves. What they are and what the cause of them is? Such queries as these are in the forefront of the thinking and study of those astronomers who have given close attention to the physical side of planetary work. Some think these markings on the planet are the work of intelligent beings belonging to that far-off world; others claim that they are natural, because the scale on which they are made is far too great for any engineering skill known to the history of such work on the Earth, if the planet is inhabited by beings like ourselves. Still others say the markings on the surface are surely there, but what they mean is less certain. They venture to suggest that they may be narrow tracts of vegetation of some kind, may be of various kinds that have a deeper hue in the spring and early summer of Mars than the same have in the fall and winter seasons. Such changes of color at the times of these different seasons are easily seen and they have been noticed and often spoken of by observers. This last view seems to be a very natural one, and it has less objection to it than any other one of which we have knowledge at present. If the melting snows of the temperate zones of the planet furnish the water for courses or streams flowing through these narrow tracts called canals, one can easily see that the effect of this natural irrigation would be to renew the foliage in the spring time and where largely used to give it the sear leaf and the dead appearance of the winter season, if the conditions of climate are at all as we suppose them to be, or if they are akin to those of the Earth.

The astronomer and the physicist really need more data before their theories can become accepted facts, and the meaning of what is seen can be better understood. While those in the forefront in planetary study are at work with great patience and energy, it may be well for those in other lines of research who are equally able and persevering in endeavor to give them at least just support and encouragement for the sake of the good results that may come to the science in which all are earnestly working and to which it is to be presumed all are equally loyal.

Before bringing this brief notice of the work on Mars during this opposition to a close we wish to call attention to a map of the surface of Mars which was prepared by Mr. Lowell in 1899, but which show, the features among others that the observers of the expedition to Chile claim to have photographed.

THE AGE OF THE EARTH'S CONSOLIDATION.*

T. J. J. SEE.

The Age of the Earth's Consolidation Calculated by the Fourier-Kelvin Method.

Considering the Earth to be a sphere of the same conductivity as average rock, we have for the rate of augmentation of temperature downward

$$\frac{d\Theta}{dx} = \frac{V}{\sqrt{\pi\kappa t}} e^{-\frac{x^2}{4\kappa t}} = \frac{1}{35.4}\frac{V}{\sqrt{t}} e^{-\frac{x^2}{1600t}}, \qquad (18)$$

κ being 400, when the units are the foot, year, and degree Fahrenheit. Solving this equation for t, and putting $V = 7000°$ Fahr., we have

$$t = \left(\frac{51}{35.4}V\right)^2 = 101{,}673{,}000 \text{ years.} \qquad (20)$$

This is Lord Kelvin's method of estimating the age of the Earth, or the duration since the beginning of the consolidation of the crust which is supposed to have occurred very soon after the initial epoch.

We have already seen that the assumption of an original uniform temperature for the Earth is only a first approximation to the true condition, not justified by a closer examination of the subject. The mathematical theory of the heat distribution in a gaseous globe shows that the temperature increases rapidly towards the center, and hence falls off correspondingly near the surface. Relatively to the average temperature of the whole mass, that of the surface is very low, and that of the center quite high. This is the condition in a gaseous sphere, and it seems certain that it cannot be greatly modified by the surface cooling which leads to encrustation. We have seen that this

* On the temperature, secular cooling and contraction of the Earth, and on the theory of earthquakes held by the ancients.

latter arises mainly from resisted circulation, and retarded supply of heat from the under layers, as the surface density increases. Prior to the beginning of surface cooling the planet passes through a stage of maximum temperature, and heat is both radiated and conducted through to the outer layers; but eventually the resistance to propagation of heat becomes so great that a fall of temperature is inevitable. In the case of the Earth there is excellent reason to conclude that the surface temperature never much exceeded 2000° Fahrenheit.

The experiments of Professors Rücker and Roberts-Austen at the Royal College of Science, London, on basalt or dolerite of Rowley Regis, undertaken at the suggestion of the Rev. O. Fisher, showed that this rock was completely fused at 1688° Fahr. Basalt is a typical rock of the Earth's crust, prevalent in nearly all volcanic districts; and it seems probable that a temperature of 2000° Fahr., would therefore not only fuse all the principal rocks of the Earth's surface but also reduce many of them to a state of vapor.

The fact that the other planets of our solar system are not at present self-luminous, though the larger masses are known to have high internal temperature, tells against the theory of a very high surface temperature also in the case of the Earth. For although we view the other planets at only one stage of their existence, and therefore cannot fully judge of their conditions at other cosmical epochs, yet the absence of self-luminosity when so much heat is known to be stored up within these planets can only indicate that a great lowering of temperature always takes place near the surface, as is also true in a sphere of monatomic gas. Thus it is not probable that even at the maximum the surface temperature of such masses would be very high. There are clear indications that Lord Kelvin's estimate of 7000° Fahr. is much too great: and in all probability we shall not be far wrong in using 2000° as the most acceptable value in all calculations on the secular cooling of the terrestrial globe. The temperature will increase with the depth, but for a shallow layer we may take it to be uniform: the temperature of 2000° then would not correspond exactly to the surface, but rather to the average of a thin sheet forming the boundary of the molten mass. As the outer layer was no doubt agitated from beneath, it would both lack in uniformity of temperature, and also be constantly changing, so that a mean temperature of 2000° Fahrenheit seems to be the closest approximation we can make to the true conditions.

Using $V = 4000°$ in formula (20), we get $t = 33{,}208{,}850$ years; which is the age of the Earth on this hypothesis. When $V = 2500°$ Fahr., we find $t = 12{,}972{,}200$ years. And if $V = 2000°$ Fahr., the result is $t = 8{,}302{,}210$ years, a comparatively short duration. As the melting temperature of basalt is less than 1688° Fahr., the smaller value for V obviously is to be preferred. Thus the assumed surface temperature of 2000° Fahr., seems sufficiently high, and our most probable age of the Earth calculated in this way is

$$t = \left(\frac{51}{35.4}\frac{V}{}\right)^2 = 8{,}302{,}210 \text{ years} \qquad (21)$$

Accordingly, we conclude from this Fourier-Kelvin formula that the age of our encrusted planet can scarcely exceed 10 million years, which accords very well with the duration inferred from the theory of the Sun's heat (cf. *A.N.*, 4053).

The Age of the Earth's Consolidation Calculated by Fischer's Method.

The Rev. O. Fisher has developed another method for calculating the age of the Earth which we shall now explain. It is in the main independent of Lord Kelvin's procedure based on Fourier's equation for the rate of increase of temperature downward, and has some advantages over it. Fisher's method is treated in Chapter vl., and also in the Appendix to the second edition of his "Physics of the Earth's Crust." He established the following formulæ:

$$\left.\begin{aligned} V &= 2\mu e^{\mu^2} M\lambda\left(1 + \frac{y}{k}\right) \\ &= 2\mu e^{\mu^2} M\lambda, \end{aligned}\right\} \quad \text{for inert substratum, in which } y = 0. \qquad (22)$$

$$\beta = \frac{V}{M\sqrt{4\kappa t}}. \qquad (23)$$

$$k = \mu\sqrt{4\kappa t}, \qquad (24)$$

$$M = \int_0^{\mu} e^{-z^2} dz.$$

In these equations μ is a function differing but little from unity; M is the definite integral $\int_0^{\mu} e^{-z^2}\, dz$; κ the coefficient of conductivity taken to be 400, as in Lord Kelvin,s work; k is the thickness of the Earth's crust; β the surface rate of augmentation of temperature downward; λ is the latent heat of molten rock measured in terms of the amount of heat required to raise one

cubic foot of the rock through 1° Fahr; and Λ is the latent heat measured in thermal units centigrade, water being the standard substance. In the appendix, p. 20, Fisher shows that Rücker's experiments make $\Lambda = 49.60$, the corresponding value for water at zero centigrade being 79.25. Taking the mean specific heat of average rock at 0.22, he makes $\lambda = 406°$ Fahr., and $V = 1688°$ Fahr. This is the temperature at which basalt is entirely melted. Finally, the quantity y is a function representing the activity of the substratum, and therefore zero when the layer is inert (cf. Chapter vl , p. 73).

Using these values Fisher finds for an inert substratum, that the true values are:
$\mu = 1.007$; $M = 0.7493736$; and the thickness of the crust

$$k = \frac{51 \times 1688 \times 1.007}{5280 \times 0.74937} = 21.91 \text{ miles.} \qquad (25)$$

He concludes that the least thickness of the crust will be $\frac{V}{\beta} = 16.30$ miles, and that the true thickness of the crust will lie between 16.30 and 21.91 miles. If we take $k = 17.5$ miles, which is very near the thickness of the crust indicated by the great earthquake which devasted San Francisco, and apply formula (24) we find for the age of the Earth

$$t = \frac{k^2(5280)^2}{\mu^2 4\kappa} = 5{,}262.170 \text{ years.}$$

Using $k = 21.91$ miles, in the same formula, Fisher finds

$$t = 8{,}248{,}380 \text{ years.} \qquad (26)$$

This age for the encrustation of the Earth seemed to him surprisingly small, and he therefore remarked:

"This is a far shorter period than geological phenomena appear to require, for although it is not possible for them to assign any definite limit to the world's age, we can form some idea of an inferior limit which it must have exceeded. Sir A. Geike thinks that the stratified rocks alone, which contain organic remains, can not have taken much less than 100 million years for their formation."

The Rev. O. Fisher then proceeds to examine the hypothesis of an energetic substratum, and by this process reaches a greater age for the world. But for reasons pointed out in the previous paper on the cause of earthquakes, the hypothesis of an inert substratum is obviously the proper one. For the substratum is shown to move only under the throes of an earthquake, and no circulatory movement of lava exists even just beneath the crust. Hence we adhere to the result there obtained, and must consider

the significance of the small age of the Earth. It will be seen that for a thickness of 22 miles, the age of the Earth's consolidation is almost exactly the same as that reached by the use of Lord Kelvin's formula.

Remarkable Agreement of the Times since the Consolidation of the Globe as concluded from these Two Methods.

The result found by Lord Kelvin's method rests upon the observed rate of increase of temperature downward, namely 1° Fahr., for 51 feet, which is about the same as the value used by Fourier nearly a century ago, and not improved upon by the deep borings made in recent years. It also rests upon the assumed surface temperature of 2000° Fahr., which probably is comparatively near the truth. Is it purely an accidental coincidence that with these data one is led by the Fourier-Kelvin formula to an age of 8,302,210 years, while by Fisher's formula, depending on the thickness of the crust essentially verified by earthquake phenomena, one finds the almost identical age of 8,248,380 years? Moderate variations of the data might derange this excellent agreement somewhat, but probably no change of the constants within admissible limits would produce extreme discordance in the resulting ages of the Earth. It seems therefore difficult to escape the conclusion that these figures really approximate the true age of our encrusted planet. At least the period since the consolidation is of the order of ten million years.

Different investigators will naturally form different estimates of the age of the Earth as found by the several methods of approximation; but it is difficult to see how the larger values formerly current can be justified by physical research based on the propagation of heat involved in the secular cooling of the globe. The writer has not the geological learning requisite for the use of the methods based on sedimentary rocks and their deposits of organic remains, but it seems very doubtful if these methods can lay claim to even approximate accuracy; and to most minds the conclusions drawn from the physical methods will naturally carry much greater weight.

Some considerations however, based on the probable average rate of the elevation of the Andes, taken at only one-tenth of an inch a year, or ten inches in a century, seem to show that the age of these mighty mountains need not much exceed three million years. In the case of the mountains west of the Rockies a numerical estimate is not quite so easy, but it is doubtful if anything authorizes an estimate exceeding five million years. In this immense period the whole country west of Laramie may

have been raised from the sea; in fact this is indicated by the abundant fossils of Saurians in the beds of Wyoming, as well as by the numerous parallel ranges of mountains in Nevada and California, showing the successive recessions of the sea. One is led therefore to think that after all our consolidated globe may not have an age exceeding eight or ten million years. In comparison with the brevity of human history such periods are almosts infinite; and so little is known of the rates of variation of organic species under the unknown conditions of the past, that we may well hesitate before assuming longer periods for the life of our encrusted planet.

In contemplating this result we are again confronted with the question of the cosmical significance of radium. Several years ago when the enthusiasm over the radium discoveries was at its height there were those who admitted a terrestrial history of a thousand million years (cf. Professor Sir G. H. Darwin's presidential address to the British Association at Capetown, 1905). But mysterious as radium still remains, it is doubtful if such a view is generally held today. It is a remarkable fact that the more we study radium, the less we seem to really understand the part it plays in cosmical processes. So far at least there is no proof that it exerts any sensible influence, except possibly in chemical transformations.

Some of the Results of the Researches on Radium.

In spite of the great labor bestowed upon the study of radium by many devoted and enthusiastic investigators, it can hardly be said that we have up to this time any conclusive results as to the cosmical significance of this very wonderful element. The theories of radium disintegration are well known, but not universally accepted. Lord Kelvin is one of those who still ascribe the Sun's heat to the potential energy of the mutual gravitation of its own matter; and he denies that radium plays any appreciable part in solar activity.

Major Dutton tried to explain the activity of volcanoes by means of periodic outbursts produced by radium, but the distribution of these vents along the shores of continents, on islands and in the sea, while none at all break out in the interior of continents, shows that there is a dependence on the oceans, and proves that radium cannot be the active cause in producing eruptions. For the experiments of the Hon. R. J. Strutt have proved that the radius is widely distributed in the rocks of the Earth's crust, such as granite; but he found on the other hand, that some basalts show scarcely a trace of it. This does not

speak favorably for the view that radium is the cause of the Earth's internal heat and volcanic outbreaks. For if radium were the cause basalts ought to be rich in the element which had caused the expulsion of this rock from volcanoes; and since all granite contains abundant radium, volcanoes ought to break out in the interior of continents, such as Africa, Australia, North and South America, Europe and Asia; but this is contrary to observation. It is not possible therefore to entertain the view that radium has any sensible connection with volcanic activity.

Of late even the terrestrial origin of radium has seemed doubtful, and in *Nature* of February 1, 1907, Professor J. Jolly, of Dublin, has suggested several considerations indicating that radium may come to us from the Sun, in the form of infinitesimal corpuscles, expelled principally by the pressure of the Sun's light. So far as we can now see this extra-terrestrial source of radium is by no means improbable. But whether this suggestion be verified by time and experience or not, it seems certain that radium in the Earth's crust is essentially dormant; at least it plays little part in the physics of planets such as the Earth, except perhaps in chemical transformations.

It probably is not without significance that in order to make the theory harmonize with the observed temperature gradient, Strutt attributes radium only to the crust, and not to the interior matter of the Earth. If radium comes from the Sun, it would lodge in the oceans, and be carried down into the sedimentary and other rocks, as now observed. In the absence of decisive proof we must suspend judgment, but at present one can only say that there is no evidence that radium is an important agency in cosmical processes witnessed upon our globe.

THE LOWELL EXPEDITION TO THE ANDES.

DAVID TODD.

FOR POPULAR ASTRONOMY.

The Lowell Expedition to the Andes, in charge of Professor David Todd of Amherst, returned to Lima, Peru, September 7. The chief instrument of the Expedition was the new 18-inch Clark refractor, which was dismounted at Amherst and transported to the Andes, especially for observing and photographing the planet Mars in its recent opposition.

For this purpose Professor Lowell had made by Gaertner of Chicago, a planetary camera from a design by Lampland

and fitted with a Wallace color screen specially adapted to the Amherst objective. Seed & Cramer ortho- and isochromatic plates were used, and about 7000 photographs of Mars were taken between June 18 and August 1st, Mr. Earl C. Slipher having been many months in training for this work under Mr. Lampland by Professor Lowell's direction, at his Observatory in Flagstaff, Arizona.

Professor Todd selected as the first station of the Expedition a spot near the heart of the desert of Tarapacá, in the elevated pampa of northern Chile, formerly part of the territory of Peru. Oficina Alianza, about 60 miles southeast of Iquique, was the location, in latitude 21° south, where Mars culminated about 5° – 7° from the zenith.

In addition to being almost constantly clear, day and night, the atmosphere was nearly all the time steady at night, the seeing rarely being below 3, and sometimes approaching 4½ on a scale of 5.

The practical and photographic work of the Expedition show the extreme benefit of such atmospheric conditions. Almost all the photographs exhibit Martian canals, so-called, or oases, or both, and perhaps 20 of the plates have unmistakably impressed upon them the double canals. The images as originally photographed are about $\frac{3}{16}$-inch in diameter, and the exposures were on the average about 1½ to 2 seconds. Many of the planetary disks will admit of a further enlargement of 3-4 diameters. The superior definition obtained was due to a further and very favorable circumstance of Alianza that the air was not only clear and steady, but always absolutely quiet at night, not even the slightest zephyr appearing to vibrate the telescope, which was mounted in the open air, with no protection except from the Sun. It will seem strange to work under a dome again.

The canals photographed double were, among others, Euphrates, Nilokeras, Thoth, Ementhes, Gihon, Astoboras and Phison. The plates exhibit a remarkable variation of the polar caps hitherto only incompletely recorded, and the stay of the expedition in Alianza was sufficiently long to secure photographs of the complete round of the Martian surface.

Other results of the expedition were a series of drawings and photographs of the disappearance of Saturn's ring, also

visual and photographic observations of the annular eclipse of the Sun, July 10, the sky during which was cloudless.

Returning to Lima, the atmospheric conditions of the higher Peruvian Andes were investigated with reference to future work, and several excellent high-level stations found, from 8,000 to 16,000 feet above the sea.

The Lowell Expedition has greatly benefited by the outside interest manifested in its work: the firm of Alvan Clark & Sons consented to the detail of their chief mechanician, Mr. A. G. Isle as instrument maker; the services of Mr. R. D. Eglesfield as electrician and assistant were gladly availed of; the Panama Railway & Steamship Company, the Pacific Steam Navigation Company, the Compañia Sud-Americana de Vaporas, the Nitrate Railways Company of Iquique, through Mr. J. Mayne Nicholl's, Manager, the Ferrocarril Central del Peru, and the Cerrode Pasco Railway Company, made generous concessions of transportation. Every courtesy was offered by vice-consul Edward E. Muecke of Iquique.

In addition the ample facilities of a great nitrate oficina were courteously provided by Messrs. Gibbs & Co., of London and Iquique, through Mr. E. F. Hamfrey and Mr. Chas. W. Evans, local representatives, and Mr. W. Brooks Comben, manager at Alianza without whose cordial coöperation and interested assistance the Expedition's work and existence in the midst of the desert would have been out of the question.

Lima, Peru.
Sept. 13, 1907.

GEOMETRICAL CONSIDERATIONS APPLIED TO THE VELOCITY OF COMETS.

JOHN B. WOOD.

FOR POPULAR ASTRONOMY.

From the geometry of the circle we have

$$\frac{k}{2r} = \frac{s}{k}.$$

Whence $k^2 = 2rs$. The exceedingly small distance s, [k being the very small chord (in ratio to $2r$) and therefore practically equal to the arc] may be taken as the fall in one second of time, measured on the diameter, $2r$.

Now the actual fall $s = \frac{g}{2}$, g being gravity or constant of motion acquired at the end of one second.

Whence we write

$$(A) \qquad k^2 = \frac{2gr}{2}$$

as formula for velocity k in a circle.

After the analogy of which, for the velocity in an ellipse, *suppose* there is written as follows: (first substitute F^2 for $2gr$)

$$(B) \qquad v^2 = y^2\left(\frac{2a-r}{2a}\right).$$

Now is there any proof that B is true, outside the higher mathematics?

We will proceed as follows. The ellipse is a curve with two centers or foci. Drawing any right angled triangle and calling the longest side a, the perpendicular, y, the horizontal, x, we have the following equation:

$$x^2 + y^2 = a^2, \text{ or } y^2 = a^2 - x^2.$$

Therefore x, (and y) are less than a. Suppose $x + q = a$. Now a is the half axis of an ellipse, of which y is the half minor axis, q is the perihelion distance of the focus at the end of $x = a - q$. Suppose, a remaining the same, the foci to approach each other. That is (using numbers as more significant of what takes place), $y^2 = 100 - x^2$, and at the start we will suppose $x^2 = 81$, $x = 9$. At this moment y was more than 4 but less than 5. At $x = 8$, $y = 6$; $x = 6$, $y = 8$; $x = 4$ gives y over 9, etc. As the focus approaches the foot of y, y lengthens and approaches $a = 10$. Therefore continuing the approach when x is exceedingly small and coming nearer to nothing y^2 approaches a^2 as its (superior) limit. Which is to say the two foci coming together at the foot of y, a coincides with y and is equal to it. Now in the curve every point is distant from the two foci and the added distances are always equal to $2a$; which, the two foci being at the same point, gives this doubly measured distance as a. In short the ellipse has been turned into a circle. To turn the statement around a circle is an ellipse which has its minor axis equal its major with the foci at the center.

Our equation B ought then to be true for a circle: v^2 corresponds with k^2, F^2 is $2gr$, but

$$\frac{2a-r}{2a}? \text{ Well, } \frac{2a-r}{2a} = \frac{2a}{2a} - \frac{r}{2a}$$

and radius $r = a$. Writing then $1 - \frac{a}{2a}$ or $1 - \frac{1}{2}$ we get $\frac{1}{2}$; $\frac{2gr}{2}$ agrees with $\frac{F^2}{2}$.

Another line of proof is open. The following equation for the velocity, in a straight line from a height to the center of the Earth on arrival at the surface, where that is r distance from the center, (g and r are both to be in *miles*).

Straight line fall:

$$v^2 = 2gr\left(1 - \frac{r}{a}\right).$$

Now although this is used to determine v *on arrival* at the surface by taking r in excess of surface distance, it is evident we get speed at that r. The a (in ratio $\frac{r}{a}$) is the total distance from start to center and therefore it can be written $2a$ as long as the ratio is maintained, [the a would not mean the same as the other a but the ratio of the part to the whole line would be the same]. The revised equation may then stand thus:

Straight line fall;

$$v^2 = 2gr\left(1 - \frac{r}{2a}\right),$$

which putting $\frac{2a}{2a}$ for 1, F^2 for $2gr$, is our B formula.

Is then an ellipse the same as a straight line? In our former equation $y^2 = 100 - x^2$ let the foci recede from the foot of y more and more. We have simply to put y for x. That is starting with $y^2 = 81$, y as 9, in succession y, 8, x, 6; y, 6, x, 8; As the focus approaches the end of $a = x + q$, x lengthens, y (and q) shorten. At the superior limit of $x = 10$, y (and q) are nothing. The line $2a$ with the foci at the ends, represents the ellipse in its other extreme.

There is one observation to be made: If we use the straight line equation making $r = a$; in the bracket we get $1 - 1 = 0$: in the result, $v^2 = 0$. There is no velocity. The interpretation of which is: r is the distance at which we are measuring, a the total distance. By putting $r = a$ we are asking for the velocity when it starts to fall; *that* velocity is of course nothing. But at the end of an ellipse, the velocity never can be nothing. Further we cannot say, supposing the possibility of a fall in a straight line to the center of the Sun, (using the pure mathematical conception of its power being concentrated in a point) that the body would first reach the solar point with speed and then rush backwards over the line after the analogy of an ellipse.

The truth is, the real meaning of the mathematical reasoning is, that an ellipse with focus almost at the end of the line $2a$ as major axis may be treated in calculation, as the *straight line* $2a$

(with r here or there on it) *with but a small amount of error;* the latter $2a$, measured out from the focus; and therefore exceeding slightly, the reach of the ellipse in space.

Riverside, California.

SPECTROGRAPHIC OBSERVATIONS OF VENUS FOR SOLAR PARALLAX.

K. BURNS.

The determination of the solar parallax by spectrographic methods has long been under consideration among astrophysicists, but until very recently it has been thought to be out of the reach of spectrographs now in use. The work of taking a series of spectrograms of stars having small latitude was begun by Sir David Gill at the Cape Observatory, and is now in progress. The accuracy with which this series will determine the solar parallax has not yet been fully ascertained; at least it has not yet been published. Professor Küstner, in an article reviewed by Dr. J. H. Moore in Vol. 17, 197, of these *Publications*, gets a p. e. of $\pm 0.22^{km}$ for a single plate of *Arcturus*; using eighteen plates, he obtained the value $8''.844 \pm 0''.017$ for the parallax.

The measures of check-plates of *Venus*, taken with the remounted Mills spectrograph in 1904 and 1905, agreed well enough to warrant the taking of a few plates at each of two successive elongations of the planet, to see what weight a value of the solar parallax would have if determined spectrographically from *Venus* alone, and to find out what increase of power would be necessary to put this method on a par with the most accurate of those now in use.

The elements of the orbit of the Earth and the other planets are well determined, but the dimensions are relative. If at any time we can determine the absolute distance from the Earth to another planet, or measure the velocity of any planet with respect to the Earth the absolute size of the whole system can be readily found. Knowing the size of the orbit of *Venus* relative to that of the Earth, the velocity of light and a few absolute wave-lengths we can determine the solar parallax by spectrographic observations of the planet.

While the velocity of *Venus* with respect to the Earth is not so great as that of the Earth with reference to a star on the ecliptic, and while the large hour angles necessary in taking

spectrograms of *Venus* are inconvenient, if not prejudicial, the brightness of the planet and freedom from unknown changes in velocity due to satellites and from small spectral variations such as may be encountered in stars, will more than counterbalance the disadvantages when we come to use a more powerful apparatus, such as we are about to discuss. The spectrographic method in general is relatively unaffected by the things that are troublesome in other methods, the most important of which is refraction, and perhaps least important on account of its accurate determination, the size of the Earth. This method must assume Doppler's principle.

The measurements of the two series of plates taken at the last two elongations of *Venus* showed greater discrepancies than had been expected, and the mean of the two sets differed by 0.4^{km}, so an investigation of the cause for the difference was undertaken. It came out that sky-plates taken with the instrument in the same adjustment as was used for the later series differed from computed values by the same amount as did the Venus-plates, leading to the conclusion that slight differences in the closure of the slit, or a dust grain, may affect the velocity of a plate by interfering with the symmetry of the comparison lines. The value obtained for the probable error of a single Venus-plate was $\pm 0.23^{km}$, of a single sky-plate $\pm 0.18^{km}$. From this we may infer that an instrument five times as powerful would give a result five times as accurate, or a p. e. of $\pm 0.04^{km}$ for a single plate, that is $\pm 0.006^{km}$ for the mean of fifty plates. This would be about the accuracy of an *Eros* determination of the parallax $\pm 0''.004$. A grating ruled 15,000 lines to the inch would give, in the third order, the same angular dispersion as the Mills at λ 4500; 20,000 lines to the inch, third order, or 15,000 lines, fourth order, would give a third more angular dispersion than the Mills, and the resolving power in either case would be over five times that of the Mills if it were a six-inch grating. The focal length of the Mills camera would have to be multiplied by 3.5 to give sufficient linear dispersion, but it might not pay to increase the collimator focal length in the same ratio, owing to the limited size of gratings that can be ruled. Supposing that this spectrograph and the horizontal telescope necessary to concentrate the light on the slit effectively utilized twenty per cent as much light as the Mills attached to the Lick 36-inch telescope. Throughout the rest of the optical train, the grating would have to throw eight per cent of the incident

light into one of the higher orders on one side—not an entirely unknown occurrence—in order to photograph the spectrum of *Venus* in thirty minutes. The Mills gives a dense negative in two minutes. If at one of the next two elongations of *Venus* which are favorable for northern observations a series of plates of the planet and the sky were taken with such a spectrograph as we have considered, and each Venus-plate measured with reference to a separate sky-plate taken the same day, the accuracy of measurement ought to be five times as great as we get with the Mills, and the probable error of a single plate should be as low as $\pm 0.04^{km}$ or $\pm 0.05^{km}$. While we may never get so accurate a value of the parallax by spectrographic methods as by the direct and indirect methods now in use, there is little doubt that a value could be obtained such that its probable error would be much less than the amount by which the values determined directly and indirectly differ, and the result might help to throw light on the cause of the present difference.

PUBLICATIONS OF THE A. S. OF P., August 10, 1907.

SPECTRUM OF COMET DANIEL (1907 *d*).

The French observers appear to have been very fortunate in their opportunities to work on this comet. At the Astrophysical Observatory of Meudon, MM. H. Deslandres and A. Bernard have successfully photographed the spectrum and discussed the probable interpretation of the lines found. Special apparatus was prepared, consisting of slitless spectrographs, and also others with the usual slits. The present note gives the results obtained with the slitless instrument, this being probably that of greatest efficiency. It gives the spectrum of the entire comet, and the confusion due to the size of the comet itself is minimized by reducing the focal length of the camera as far as possible. Two spectrographs of this type were employed (1) having a flint prism of 60° angle, with an objective of 21 cm. focal length and aperture 4.8 cm.; (2) with a prism and objective of quartz (ratio of aperture to focus = 1.15). They were carefully adjusted and rigidly mounted on an equatorial so that the edges of the prisms were parallel to the length of the tail of the comet. The mounting also carried a visual refractor of 6 inches aperture,

and an ordinary photographic camera without prism. After the exposure on the comet spectrum, the spectrum of a bright star was photographed on either side of that of the comet, for determination of wave-lengths. In this way interesting negatives were obtained on August 9, 15 and 20 Lumière plates being employed.

The cometary spectrum is sharp and strong, consisting of the three bands, yellow, green, and blue (λ 473) usually ascribed to hydrocarbons, and also the ultra-violet cyanogen band (λ 388), which was first recognized in the comet of 1881 by Huggins. A peculiarity is that these bands, at least those of hydro-carbon, do not appear to show the usual maximum of intensity towards the more refrangible edge, but this can only be definitely settled by discussion of the slit spectrograph plates.

Besides these strong bands, the negative of August 20 shows several fainter ones, λ 458-452, λ 429-423, λ 404-400, which have the peculiarity that they are projected in the tail quite 45 minutes of arc from the nucleus, while the strong bands are confined to the neighborhood of the head and nucleus. The nucleus also shows additional faint bands which are not represented in the tail, at λ 438-433, λ 423-420.5, λ 420-417.5, so that we are here furnished with a remarkable differentiation between the constitution of the head and tail of the comet. The chemical origin of these bands cannot be definitely stated at present. The central band, λ 429-423, is very near a strong band emitted by the blue cone of a bunsen flame, and the two feeble bands at λ 455 and λ 402 are near the two hydrogen lines of the secondary series, discovered by Pickering, in ζ Puppis.

Excellent photographs of the comet have been obtained at Greenwich Observatory with the 39-inch reflector. These show the tail to be composed of from 15 to 20 streamers, with indications of still more complicated structure. A beautiful transparency of one of these photographs may now be seen at the Photographic Exhibition at the New Gallery. Other photographs taken with a Dallmeyer rectilinear lens, show the tail to extend some 7° from the head of the comet. The general direction of the tail was west, the streamers spreading out in fan-like form and curving round to the south.

KNOWLEDGE AND SCIENTIFIC NEWS, October 1907.

THE RED SPOT ON JUPITER.

A. STANLEY WILLIAMS.

The times of transit of the Red Spot observed here during the past opposition of Jupiter are given in the second column of the table below. They are all simple eye-estimates of the times when the spot was in mid-transit across the planet's disk, no micrometer being used. The spot was extremely faint, perhaps as faint as it ever has been, whilst the weather was very unfavorable, particularly in the early part of the apparition. Not only were clouds unusually prevalent but the seeing on a large proportion of the nights was of the poorest.

OBSERVED TIMES OF TRANSIT OF THE RED SPOT.

1906-07		Gr. m. t. of Transit h	m	wt.	Long °	O − C m	Note
Aug.	15	15	57.3	1	18.3	+4.7	1
	27	15	47.1	(2)	14.1	−3.0	
Sept.	15	16	36.4	1	17.7	+1.6	2
	25	14	49.7	1	15.5	−2.6	3
	30	14	1.7	1	17.8	−0.8	4
Oct.	14	15	36.2	1	18.7	+1.4	5
	27	11	17.7	1	16.5	−3.1	6
Nov.	10	12	49.0	1	16.5	−3.9	7
	17	13	34.3	1	16.5	−4.5	8
	22	12	46.8	2	19.7	+0.5	9
	27	11	53.4	2	19.3	−0.5	10
Dec.	7	10	6.8	2	18.9	−1.8	
	9	11	45.6	1	19.5	−1.1	11
	21	11	41.2	3	21.8	+2.0	
Jan.	11	14	0.1	2	24.0	+4.3	
	17	8	58.8	3	24.0	+3.9	12
	26	11	27.0	1	26.5	+7.5	13
Feb.	22	8	40.3	2	22.6	−0.8	
Mar.	1	9	26.2	3	21.7	−2.7	
	3	11	3.4	1	20.7	−4.5	14
	6	8	34.8	2	21.5	−3.5	15
	20	(10	6.6)	1	(18.8)	(−8.8)	16
	25	9	23.2	2	23.1	−2.0	
April	4	7	45.5	1	25.0	+0.5	17
	6	9	26.1	2	26.0	+1.9	18
	11	8	33.3	2	24.4	−1.0	
	18	9	25.5	2	26.4	+1.9	

NOTES. 1) Rough observation, frequent rain clouds. 2) Spot faint, seeing very bad. 3) Rough obs. 4) Cloud and poor seeing. 5) Much cloud. 6) Rough obs. 7) Exceedingly rough, a glimpse through nearly continuous cloud. 8) Spot faint, seeing bad and frequent clouds. 9) Spot well seen and not difficult. 10) Spot very faint, with a patchy aspect. 11) Seeing bad. 12) Spot well seen and had a slightly reddish tinge. 13) Seeing bad. 14) Exceedingly rough, East wind.

15) Spot plain. 16) Very rough, seeing very bad. 17) Very rough, seeing very bad. 18) Spot plain except at the preceding end.

The longitude of the spot according to system II of Mr. Crommelin's Ephemeris will be found in the fourth column of the table. The weights in the third column are on a scale ranging from 1 (bad) to 5 (perfect satisfaction). In the last column are the differences O — C corresponding to a rotation period of $9^h\ 55^m\ 42^s.27$, which appears to satisfactorily represent the observations. These differences are somewhat large, the mean error of an observation being $\pm\ 2^m.55$. This is only what might be expected, since, for the reasons already stated, the present series of observations is an indifferent one, and cannot be considered for a moment as being representative of the degree of accuracy attainable by the method of eye-estimated transits. The observation of August 27 was a peculiar one. On this night there was a large dark protuberant spot visible on the S. Temperate belt, just preceding the Red Spot, and apparently contouring the south preceding outline of the latter, and the observation was made on the assumption that this was the case. Later on, however, when this dark spot had drifted farther to the west, it was seen to still preserve its former shape. It is possible, therefore, that at the time of the observation of August 27 it may not have been in actual contact with the Red Spot, especially since the observed time of transit is somewhat early. Because of this uncertainty the observation has been treated as of weight 1, instead of 2, as recorded at the time.

Reduced to the date of opposition (1906 December 28) the weighted mean time of transit from all observations, excepting that of March 20, is $12^h\ 24^m.63$, with a probable error of $\pm 0^m.38$. The corresponding longitude is $20°.87$, with a probable error of $\pm 0°.23$. The rotation period satisfying the observations is $9^h\ 55^m\ 42^s.27$ (594 rotations). Between 1906 August 15 and 1907 April 18 the rate of motion of the spot was probably uniform, though the grouping of the residuals in the last column of the table is suggestive of the existence of slight minor fluctuations in the motion of the spot.

But when we compare the present results with those derived from the observations of the previous opposition, a very remarkable change becomes evident. The rotation period

of the spot in the apparition of 1905–06 was $9^h\ 55^m\ 41^s.46$*, whilst in that of 1906-07 it was as already stated, $9^h\ 55^m\ 42^s.27$. But the rotation period in the interval from one opposition to another was much shorter than either of these, being in fact as short as $9^h\ 55^m\ 36^s.25$. This difference is far too large to be attributed to errors of observation; and hence it is quite certain that the larger part of it at least must be due to a real change in the rate of motion or, what amounts to the same thing, to an actual shift in the position of the Red Spot itself. It is the existence of such large and undoubtedly real changes which renders it impossible at present to come to any definite conclusion respecting the presence of a form of systematic error in the method of observation, such as that referred to in Astr. Nachr. No. 4150, col. 348. The remarkable nature of the recent change is even more apparent if we compare the position of the Red Spot at the end of the apparition of 1905-06 with that occupied by it at the commencement of that of 1906-07. Thus, in April 1906 the longitude of the spot was 30°, whilst in the middle of August it was about 16°. The difference is 14°, equivalent to an interval of 23^m in the time of transit.

With regard to the cause of this remarkable change, it will be remembered that at the end of the apparition of 1905-06, the great quantity of dark material, constituting what has been variously termed the Pyramid Spot, the Schleier marking and the South Temperate or South Tropical disturbance, had overtaken, but had not yet passed, the Red Spot. By the middle of August this dark material had all drifted to the westward clear of the Red Spot. The remarkable shift of the latter to the westward of its former position must therefore have occurred at the time when the material of the Disturbance was drifting past it. On three separate and consecutive occasions, therefore, the passage of this great quantity of dark material past the Red Spot has now synchronized closely with an acceleration in the motion of the latter, so that there can no longer be much doubt as to the one marking having been influenced by the other. A full discussion of all available observations may not improbably eventually throw much valuable light upon the nature and possibly the mass of the Red Spot. The compar-

* Astr. Nachr. No. 4150.

atively sudden nature of the changes would seem to imply that the mass of the Red Spot is comparatively insignificant, probably considerably less than that of the material and constituting the S. Tropical Disturbance. Its density also would appear to be but slight. Before any adequate discussion can be made, however, it will be necessary to wait until all the observations of both the Spot and the Disturbance shall have been published. It is very much to be hoped, also, that further micrometer observations of both objects have been made and will be published shortly.

ASTRONOMISCHE NACHRICHTEN, No. 4202.

SOLAR OBSERVATORY WORK.*

GEORGE E. HALE.

SPECTRA OF SUN-SPOTS.

In my last annual report, reference was made to the fact that photographs showing widened lines in the spectra of sun-spots had been obtained, and that steps would be taken to interpret these phenomena through experiments in the laboratory. The investigation which has grown out of this work has been alluded to in the introduction to the present report. The photographs of the spectra of sun-spots, made by Mr. Adams and Mr. Ellerman, after the Littrow spectrograph of the Snow telescope had been given its permanent form, proved so satisfactory that they have served as the basis of our studies. It should be remembered that the principal phenomena of spot spectra comprise: (1) Fraunhofer lines of the same intensity as those of the solar spectrum; (2) lines that are widened or strengthened; (3) lines that are weakened or replaced by bright lines. The photographs successfully register not only the more conspicuous lines of these types, but also the multitude of fine lines into which the spot spectrum was visually resolved by Professor Young many years ago. In my photographic work on spot spectra at Yerkes Observatory, which was done with the assistance of Mr. Ellerman, a few of the more conspicuous of these fine lines were recorded, but the scale of the spectrum was so small that their identity could not be determined with any certainty. The present photographs

* Report of the Director, 1907.

have a scale five times as great, with the result that thousands of the fine lines appear upon the plates, where their positions can be measured with precision. Measurements of these lines, by Mr. Adams, have shown that most of them are identical in position with the extremely faint lines recorded by Rowland in the solar spectrum. In other words, this feature of the spot spectrum is produced by a marked strengthening of the absorption of the solar atmosphere. However, the conclusion drawn by Dunér, from his visual observations, "that there is no fundamental difference between the general solar spectrum and that of the spots," is by no means warranted, for the intensities of the lines which are strengthened are not increased, in all cases, in the same proportion; on the contrary, the changes show the widest variations, some lines being unaffected, some enormously increased in intensity, and others greatly enfeebled.

The identification of the faint lines in the spot spectrum, although it cleared up the uncertainty as to their origin, by no means solved the problem regarding the cause of the characteristic spectral phenomena of spots. It seemed evident that extensive laboratory investigations might be needed for this purpose. The question was however, to find some logical basis for a plan of attack. I have long been impressed with the following characteristic features of spot spectra: (1) The diverse behavior of different lines of the same element; (2) the fact that all of the strengthened lines lie in the visible spectrum, and that the most conspicuous of them are in the red, yellow, and green, and (3) the relatively great intensity in the less refrangible region of the general background of the spot spectrum. In considering these peculiarities, I could not fail to recall: (1) That in the spectra of the elements some lines increase in intensity, while others decrease, when the temperature falls; (2) that in spectra observed at low temperatures, the most prominent lines are likely to appear in the less refrangible region; and (3) that in a continuous spectrum (as well as in a spectrum of bright lines) a reduction in temperature involves a shift of the maximum toward the red. The similarity of these two groups of facts led to the belief that the most characteristic phenomena could in all probability be accounted for on the hypothesis that the temperature of the vapors within the spot is below that of the corresponding vapors within the Sun's reversing layer. It was on this basis

that the laboratory investigations, described on another page of this report, were undertaken.

The results so far obtained in our study of spot spectra, while strongly confirmatory of the hypothesis outlined above, of course constitute only the first steps in the extended researches required to test it in a complete manner. The use of an electric furnace, for the vaporization of metals in a carbon tube, where no electrical phenomena, other than those which result in the production of heat, can influence their radiation, is a most important element in the general investigation. This work which is now in progress, will include all of the characteristic sun-spot metals that can be volatilized in the furnace. The solar side of the investigation will involve photographic and visual studies of spot spectra carried on through a period of several years. Further stellar spectroscopic investigations must be delayed until the completion of the 60-inch reflector, as the Snow telescope is not well adapted for this phase of the work.

It must not be supposed that our hypothesis is intended to account for all of the phenomena of spot spectra. The bright lines occasionally observed are probably due to the overlying reversing layer, or to the chromosphere, especially in cases where eruptive action is concerned. The hypothesis will serve a useful purpose if it provides a basis for the interpretation of the principal phenomena of strengthened and weakened lines, at the same time permitting an estimate of the approximate temperature of the vapors within the spot. Our work also appears to throw light on the much discussed question of the "enhanced" lines, favoring, as it does, the view that temperature alone is sufficient, in most cases, to account for these lines, though by no means precluding the view that high electrical potential, or sudden change of potential, may be capable of producing similar effects. Special attention will be given to these latter questions in our laboratory investigations.

Radial Motion of the Calcium Vapor in the Flocculi.

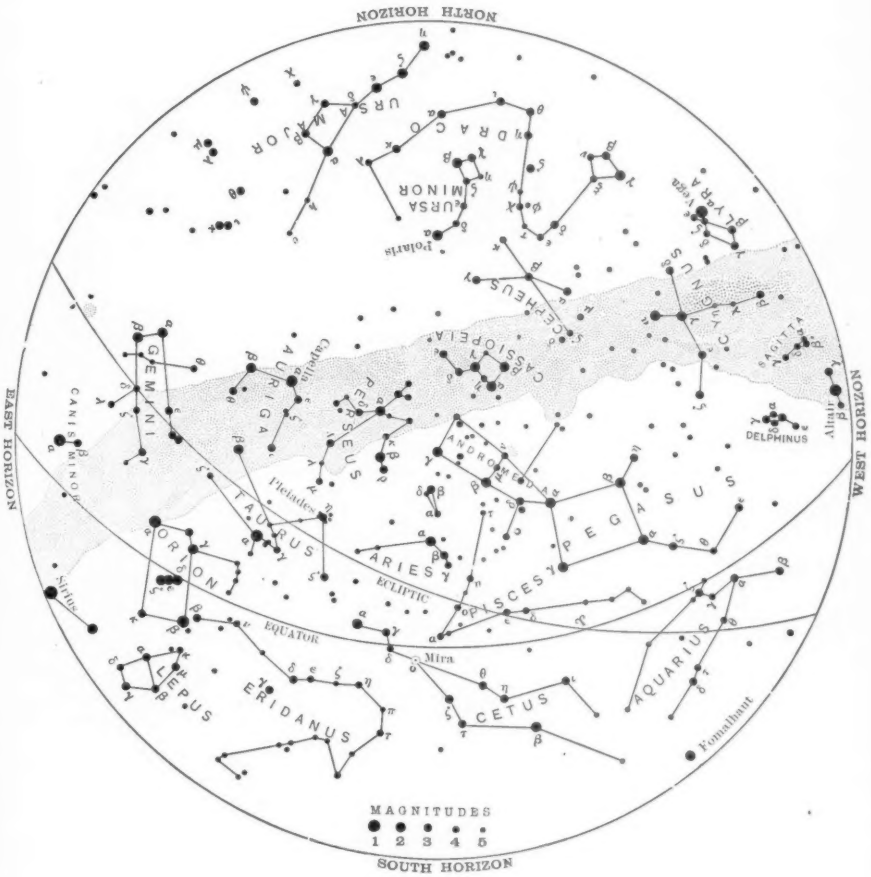
In connection with the study of the spectra of sun-spots, the work of Mr. Adams on the wave-length of the H and K lines in flocculi, and the motion of the calcium vapor in the Sun, * is of great importance. As the spectroheliograph so

* Contributions from the Solar Observatory, No. 6.

clearly shows, sun-spots are surrounded by extensive flocculi, consisting of cloudlike masses of calcium vapor, which sometimes overhang the smaller spots, so as to hide them completely. These calcium clouds rise from the faculæ, and they are presumably the effects of convection currents proceeding outward from the interior of the Sun. It is evident that the radial motion of the vapor should be measurable from the displacements of the H_2 and K_2 lines, which correspond to the lower and intermediate regions of the chromosphere, and those of the H_3 and K_3 lines, which are produced by the absorption of the cooler vapor at a somewhat higher level. Mr. Adams's investigation began with a redetermination of the wave-lengths of the H and K lines in the electric arc, since the available determinations were not in sufficiently close agreement to promise the necessary accuracy. The large scale of the photographs, which were made with the Littrow spectrograph, permitted them to be measured with high precision, and the resulting wave-lengths of the H and K lines are probably very close to the truth. Using the arc lines as standards, Mr. Adams determined the wave-lengths of the H_2 and K_2 lines, and those of the H_3 and K_3 lines, at various points on the solar surface, and also (for the latter lines) over sun-spots. The average displacement of H_3 and K_3, which amounted to 0.006 tenth-meter toward the violet, corresponds to a velocity of approach of the vapor amounting to 0.41 kilometer per second. The varying displacements obtained at different times, however, indicate that general conclusions should be based only on a very extensive investigation. The results given by the bright lines H_2 and K_2 also show a displacement toward the violet, so that it is probable that the calcium vapor in the flocculi may be regarded as moving upward. This would accord with the conclusions as to the nature of these objects based upon work with the spectroheliograph. As already stated, however, much more work along these lines must be undertaken, and special apparatus has accordingly been prepared for this purpose.

PLANET NOTES FOR DECEMBER 1907.

H. C. WILSON.



THE CONSTELLATIONS AT 9:00 P. M., DECEMBER 1, 1907.

Mercury is morning star visible toward the southeast about an hour before sunrise during the first week of December.

Dont forget the transit of Mercury on the morning of November 14.

Venus is evening star and may be easily recognized near the southwestern horizon an hour after sunset. The phase of Venus is nearly full, 0.945 of the diameter of the disk being illuminated. Venus and the crescent Moon will be near together on the evening of December 6.

Mars is moving steadily northeastward, and will pass through Aquarius during this month. Mars will be in conjunction with Saturn on the morning of December 31. For several days the two planets will be near each other, Mars passing about two degrees to the north of Saturn. The contrast in color of the two planets will be conspicuous.

Jupiter is a morning planet, being near the meridian at 4 a. m.

Saturn is visible in the early evening and will be at quadrature, 90° east from the Sun, on December 13. On the night of October 12 as the planet was observed with the 16-inch telescope at Goodsell Observatory, the planet appeared ringless, only a very faint flash of light being occasionally glimpsed from either *ansa* of the ring. One of the satellites was visible quite close up to the planet on the preceding (west) side. A fine black line, the shadow (?) of the rings, was visible across the equator of the planet and by imagination could be carried across the satellite also; but the seeing was not good enough to make sure whether the apparent effect upon the satellite was real or not. According to the data of the *American Ephemeris* the Earth passed through the plane of the rings from south to north on October 4 and on October 12 was at an angle of about 15′ above that plane, while the Sun was 1° 11′ below it and so was shining on the opposite side of the rings.

Uranus is too near the Sun for observation now. This planet will be almost exactly one degree north of Venus on December 11 at 12^h Greenwich mean time.

Neptune is in Gemini a little way northeast of the star ζ. The position of the planet for December 1 is R. A. 7^h 02^m 06^s, Dec. + 21° 50′.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Dec. 10	56 Aquarii	6.1	5 04	106	6 01	198	0 58
11	BD.—10° 6120	6.3	8 29	137	8 43	162	0 14
17	δ^1 Tauri	3.9	5 28	83	6 29	232	1 01
17	δ^3 Tauri	4.3	7 00	53	8 12	259	1 12
20	δ Geminorum	3.5	18 55	79	19 49	301	0 54
28	Piazzi xiii, 174	6.4	17 35	65	18 17	2	0 42

Satellites of Saturn.

[The diagram of the orbits of the satellites cannot be shown since the Earth passed the planes of the orbits at different times during September and October.]

Central Standard Time reckoning from noon.

I Mimas. Period 0^d 22^h.6.

	h		h		h		h
Dec. 2	10.9 W.	Dec. 11	9.8 E.	Dec. 20	8.8 W.	Dec. 28	8.9
3	9.5 W.	12	8.4 E.	21	7.4 W.	29	7.5
4	8.1 W.	13	7.0 E.	22	6.0 W.	30	6.1
5	6.7 W.	14	5.7 E.	23	4.7 W.	31	4.8
6	5.4 E.	15	4.3 E.				

II Enceladus. Period 1^d 8^h.9.

Dec. 1	22.3 E.	Dec. 8	18.7 E.	Dec. 17	0.1 E.	Dec. 23	20.5 E.
3	7.2 E.	10	3.6 E.	18	8.9 E.	25	5.4 E.
4	16.0 E.	11	12.5 E.	19	17.8 E.	26	14.3 E.
6	0.9 E.	14	6.3 E.	21	2.7 E.	27	23.2 E.
7	9.8 E.	15	15.2 E.	22	11.6 E.	29	8.1 E.
						30	17.0 E.

III Tethys. Period $1^d\ 21^h.3$.

Dec.	2	9.0 E.	Dec. 9	22.3 E.	Dec. 17	11.5 E.	Dec. 25	0.8 E.
	4	6.3 E.	11	19.6 E.	19	8.9 E.	26	22.1 E.
	6	3.6 E.	13	16.9 E.	21	6.2 E.	28	19.5 E.
	8	1.0 E.	15	14.2 E.	23	3.5 E.	30	16.8 E.

IV Dione. Period $2^d\ 17^h.7$.

Dec.	1	21.2 E.	Dec. 10	2.3 E.	Dec. 18	7.4 E.	Dec. 26	12.6 E.
	4	14.9 E.	12	20.0 E.	21	1.1 E.	29	6.3 E.
	7	8.6 E.	15	13.7 E.	23	18.9 E.		

V Rhea. Period $4^d\ 12^h.4$.

Dec.	5	6.5 E.	Dec. 14	7.4 E.	Dec. 23	8.4 E.	Dec. 27	20.9 E.
	9	19.0 E.	18	19.9 E.				

VI Titan. Period $15^d\ 22^h.7$.

Dec.	3	10.0 E.	Dec. 11	10.9 W.	Dec. 19	9.1 E.	Dec. 27	10.3W.
	7	13.6 I.	15	6.8 S.	23	12.9 I.	31	7.6 I.

VII Hyperion. Period $21^d\ 06^h.6$.

Dec.		4.5 I.	Dec.	13.6 S.	Dec.	25.8 I.	Dec.	30.4 E.
		9.2 W.		18.6 E.				

VIII Iapetus. Period $79^d\ 7^h.9$.

Nov.	18.3. I	Dec.	8.6 W.	Dec.	28.4 S.

COMET AND ASTEROID NOTES.

A Photographic Observation of Mellish's Comet *b* 1907.—In *A. N.* 4199 Professor E. E. Barnard gives an account of photographs of this comet obtained by him on the night of April 13 before the announcement of the discovery by Mellish. Professor Barnard was photographing the region of Giacobini's comet *a* 1907, and found the trail of Mellish's comet near the corner of the same plates, taken with the ten-inch and six-inch cameras.

Ephemeris of Comet *d* 1907. The following ephemeris taken from *A. N.* 4200 is based upon the elements by Geo. Dybeck, which were given in our August-September number. The comet will be far enough out of the morning twilight to be observed during December.

Berlin Midnight 1907	R. A. h m s	Dec. ° ′	log *r*	log Δ	Br.
Nov. 4	13 12 24	−3 55.3	0.1402	0.3489	0.71
12	13 29 56	−5 10.6	0.1792	0.3664	0.53
20	13 45 46	−6 14.5	0.2144	0.3809	0.42
28	14 00 03	−7 08 0	0.2462	0.3929	0.35
Dec. 6	14 12 54	−7 51.6	0.2753	0.4025	0.29
14	14 24 29	−8 26.2	0.3020	0.4096	0.25
22	14 34 48	−8 51.8	0.3268	0.4146	0.21
30	14 43 48	−9 09.2	0.3497	0.4176	0.19

New Comet *e* 1907 (Mellish).—A telegram received October 16 announces the discovery of a new comet by John E. Mellish of Cottage Grove (near Madison) Wisconsin, on the morning of October 14, in R. A. $8^h\ 31^m$, Dec. — 9° 24′. The comet is described as visible with an opera-glass and moving slowly northwest.

As observed at Goodsell Observatory on the morning of October 17, the comet was easily picked up with the 5-inch finder, and appeared almost perfectly round, with a strong central condensation but no definite

nucleus. Its diameter was perhaps 5′. In the 16-inch telescope there was a suspicion of a stellar nucleus but it was too faint to assist much in the measures of the comet's position.

When discovered the comet was about 15° directly south of the head of Hydra and its course lies lengthwise of the constellation Monoceros, aiming for a point midway between the stars γ Geminorum and α Orionis. On November 1 it will be about one quarter of the way on a line from Procyon to the belt of Orion.

The following observations are all that have come to hand at this writing (October 21):

Gr. M. T.	R. A. h m s	Dec. ° ′ ″	Observer	Place
Oct. 13.9	8 31	−9 24	Mellish	Madison
15.6784	8 26 13.2	−8 45 16	Hartwig	Bamberg
15.9165	8 25 33	−8 39 25	Frederickson	Washington
16.9100	8 22 38.4	−8 13 51	Wilson	Northfield
16.3102	8 22 37.5	−8 13 52	Frederickson	Washington
16.9782	8 22 25.1	−8 12 06	Duncan	Mt. Hamilton
17.9208	8 19 27.8	−7 46 15	Wilson	Northfield
17.9892	8 19 13.1	−7 44 15	Duncan	Mt. Hamilton

Elements have been computed by Miss Lamson at Washington and by H. C. Wilson at Northfield, which agree fairly well considering the shortness of the intervals between observations.

PRELIMINARY ELEMENTS OF COMET *c* 1907.

Computer	Lamson	Wilson
T =	1907 Sept. 12.47	Sept. 16.64
ω =	291° 42′	297° 44′
Ω =	55 32	53 57
i =	118 53	119 55
q =	0.973	0.996
Dates of Obs. =	Oct. 15, 16, 17	Oct. 15, 16, 17.

EPHEMERIS FROM MISS LAMSON'S ELEMENTS.

Gr. midnight	R. A. h m s	Dec. ° ′	Brightness
Oct. 19	8 14 04	−7 00	1.15
23	7 57 41	−4 38	
27	7 36 01	−1 30	
31	7 06 49	+2 39	2.06

It appears from these approximate elements that, although the comet was at perihelion September 12 and is now receding from the Sun, it is still coming nearer to the Earth and the Earth is also approaching its path. The distance between the two will be shortest somewhere about November 10. The comet is not likely to become more than three times as bright as at the time of its discovery.

A later telegram received at Harvard observatory from Professor A. O. Leuschner at Berkeley, California, states that the following elements and ephemeris of Mellish's comet have been computed by Crawford, Glancy and Morgan from observations on Oct. 15, 16, 17.

ELEMENTS.

Time of passing perihelion	= T = 1907, Sept. 16.^{d}13 G. M. T.
Perihelion minus node	= ω = 296° 46′
Longitude of node	= Ω = 53 36
Inclination	= *i* = 120 12
Perihelion distance	= *q* = 0.987

	Ephemeris.		
G. M. T.	R. A.	Dec.	Light.
	h m s	° ′	
1907 Oct. 19.5	8 13 59	−6 59	1.13
23.5	7 57 4	−4 31	
27.5	7 33 52	−1 10	
31.5	7 1 15	+3 30	2.31

Ephemeris of Planetoid 471 Papagena.—In *A. N.* 4200 Mr. Gustaf Strömberg, assistant at the observatory in Stockholm, gives an ephemeris of this asteroid. The opposition will occur October 27, when the brightness of the planet is estimated at $8^m.5$. The planet will be at perihelion November 30 so that this opposition is very favorable for observation.

Berlin Midnight 1907	R. A.	Dec.	log *r*	log Δ
	h m s	° ′		
Oct. 27	1 45 8	−13 13.9	0.3500	0.1154
29	43 21	13 08.4		
31	41 37	13 01.7		
Nov. 2	39 56	12 53.7		
4	38 19	−12 44.6	0.3494	0.1234
6	36 46	12 34.0		
8	35 17	12 22.3		
10	33 53	12 09.5		
12	32 36	−11 55.5	0.3489	0.1357
14	31 23	11 40.3		
16	30 17	11 24.2		
18	29 17	11 07.0		
20	28 24	−10 48.8	0.3486	0.1516
22	27 38	10 29.7		
24	26 58	10 09.8		
26	26 25	9 49.1		
28	1 25 58	− 9 27.6	0.3485	0.1702

VARIABLE STARS.

New Variable 136.1907 Andromedæ.—In *A. N.* 4198 Professor W. Ceraski announces a new variable in Andromeda which is probably of the Algol type. The star is BD + 42°28 magnitude 9.5 and its position according to the BD:

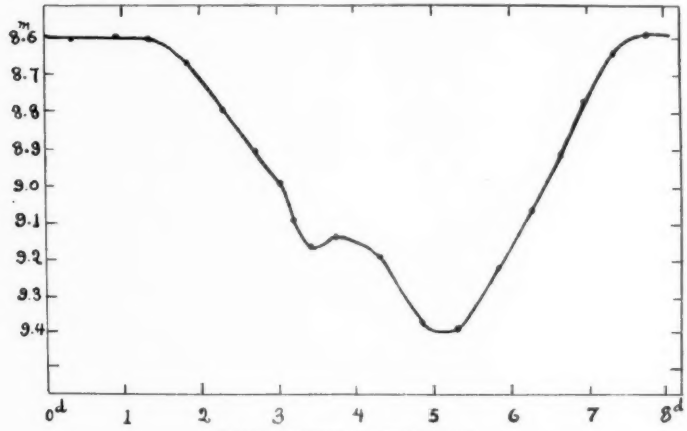
1855.0 R. A. = 0^h 05^m $42^s.3$ Dec. = + 42° 54′.3
1900.0 = 0 08 02 .2 = + 43 09 .3

Out of seventeen plates obtained in the interval from 1904 to 1907, one only showed the variable fainter than the surrounding stars of the same ordinary brightness. During the summer of this year, from May to August, M. Blajko observed the star thirty-two times, always finding it about 9.6 magnitude. At last on August 8 at 11^h 11^m, Moscow mean time, he found it about 1.2 magnitudes fainter than usual. It remained the same until 13^h 15^m, and perhaps until 14^h 10^m, but the last observation was interfered with by clouds.

Elements and Light Curve of VY Cygni. In *Bulletin Astronomique* for September 1907 Mr. M. Luizet of Lyons, France, gives new

elements of the variable star VY Cygni depending upon his own observations, 57 in number, from November 30, 1905 to January 12, 1907 together with the published observations of Williams, Seares and Haynes. The new elements are

Maximum = J. D. 2416370.948 Gr. M. T. + $7^d.85925$ E
= 1903 Sept. 12 22^h 58^m Gr. M. T. + 7^h 20^h 37^m 23^s E.



LIGHT CURVE OF VY CYGNI

The minimum occurs 2^d 14^h before the maximum and the light at maximum remains almost constant for about two days.

According to the light curve the decrease of light is slower and less regular than this increase.

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Dec.	10	22
	25	17

RX Aurigæ

	(−4	0)
Dec.	20	6
	21	21

Y Aurigæ

	(−0	18)
Dec.	3	13
	7	10
	11	7
	15	3
	19	0
	22	20
	26	17
	30	14

T Monoc.

	d	h
	(−7	23)
Dec.	16	9

W Geminorum

	(−2	22)
Dec.	3	1
	10	23
	18	21
	26	19

ζ Geminorum

	(−5	0)
Dec.	10	21
	21	1
	31	5

V Carinæ

	(−2	4)
Dec.	2	9
	9	2
	15	18
	22	11
	29	4

T Velorum

	d	h
	(−1	10)
Dec.	3	0
	7	15
	12	7
	16	22
	21	13
	26	5
	30	20

W Carinæ

	(−1	0)
Dec	5	4
	9	13
	13	22
	18	7
	22	16
	27	1
	31	10

S Muscæ

	d	h
	(−3	11)
Dec.	6	15
	16	7
	25	22

T Crucis

	(−2	2)
Dec.	6	10
	13	4
	19	22
	26	15

R Crucis

	(−1	10)
Dec.	6	12
	12	8
	18	4
	24	0
	29	20

S Crucis

	d	h
	(−1	12)
Dec.	1	5
	5	21
	10	14
	15	7
	19	23
	24	16
	29	8

W Virginis

	(−8	5)
Dec.	14	3
	31	9

V Centauri

	(−1	11)
Dec.	5	8
	10	20
	16	8
	21	20
	27	7

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

R Triang. Austr.

	d	h
	(−1	0)
Dec.	2	20
	6	6
	9	15
	13	0
	16	10
	19	19
	23	4
	26	14
	29	23

S Triang. Austr.

	d	h
	(−2	2)
Dec.	3	2
	9	9
	15	17
	22	1
	28	9

S Normæ

	d	h
	(−4	10)
Dec.	6	5
	15	23
	25	17

U Aquilae

	d	h
	(−2	4)
Dec.	7	15
	15	15
	21	16
	28	17

XZ Cygni

Period $11^h.2$

	d	h
Dec.	1	29
	2	17
	3	16
	4	14
	5	13
	6	11
	7	9
	8	8
	9	6
	10	5
	11	3
	12	1
	13	0

XZ Cygni

	d	h
Dec.	13	22
	14	21
	15	19
	16	17
	17	16
	18	14
	19	13
	20	11
	21	9
	22	8
	23	6
	24	5
	25	3
	26	1
	27	0
	27	22
	28	20
	29	19
	30	17
	31	16

U Vulpeculae

	d	h
	(−2	3)
Dec.	1	0
	9	0
	16	23
	24	23

SU Cygni

	d	h
	(−1	7)
Dec.	3	21
	7	17
	11	13
	15	10
	19	6
	23	2
	26	22
	30	19

η Aquilae

	d	h
	(−2	6)
Dec.	3	1
	10	6
	17	10
	24	14
	31	18

S Sagittae

	d	h
	(−3	10)
Dec.	1	13
	9	22
	18	7
	26	16

V Vulpeculae

Minimum

	d	h
Dec.	13	0

X Cygni

	d	h
	(−6	19)
Dec.	14	21
	31	6

T Vulpeculae

	d	h
	(−1	10)
Dec.	3	6
	7	17
	12	3
	16	14
	21	0
	25	10
	29	21

TX Cygni

	d	h
Dec.	1	18
	16	12
	31	5

WZ Cygni

Minimum

Period $14^h.$

	d	h
Dec.	1	11
	2	15
	3	19
	4	23
	6	3
	7	8
	8	12
	9	16
	10	20
	12	0
	13	4
	14	8
	15	12
	16	16
	17	20

WZ Cygni

	d	h
Dec.	19	0
	20	4
	21	8
	22	12
	23	16
	24	20
	26	0
	27	4
	28	9
	29	13
	30	17
	13	21

RV Capricorni

Period $10^h.7$

	d	h
Dec.	1	8
	2	5
	3	3
	4	0
	4	22
	5	19
	6	17
	7	14
	8	12
	9	9
	10	7
	11	4
	12	2
	12	23
	13	21
	14	18
	15	16
	16	13
	17	11
	18	8
	19	6
	20	3
	21	0
	21	22
	22	19
	23	17
	24	14
	25	12
	26	9

RV Capricorni

	d	h
Dec.	27	7
	28	4
	29	2
	29	23
	30	22
	31	19

VY Cygni

	d	h
	(−2	2)
Dec.	8	17
	16	14
	24	10

VZ Cygni

	d	h
	(−2	12)
	(−3	6)
Dec.	6	2
	11	2
	15	19
	20	19
	25	13
	30	13

δ Cephei

	d	h
	(−1	10)
Dec.	5	18
	11	3
	16	12
	21	21
	27	5

V Lacertæ

	d	h
	(−1	17)
Dec.	2	15
	7	14
	12	14
	17	14
	22	13
	27	13

88.1906 Lacertæ Minimum

	d	h
Dec.	3	7
	8	17
	14	4
	19	14
	25	1
	30	12

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Dec.	1	17
	4	4
	6	16
	9	4
	11	16
	14	4
	16	15
	19	3
	21	15
	24	3

U Cephei

	d	h
Dec.	26	14
	29	3
	31	14

Z Persei

	d	h
Dec.	3	23
	7	1
	10	2
	13	3
	16	5
	19	6

Z Persei

	d	h
Dec.	22	7
	25	9
	28	10
	31	11

RX Cephei

	d	h
Dec.	21	7

Algol

	d	h
Dec.	2	18
	5	15
	8	12

Algol

	d	h
Dec.	11	9
	14	5
	17	2
	19	23
	22	20
	22	16
	28	13
	31	10

RT Persei

	d	h
Dec.	1	18

RT Persei

	d	h
Dec.	2	15
	3	11
	4	7
	5	4
	6	0
	6	21
	7	17
	8	13
	9	10
	10	6

Minima of Variable Stars of the Algol Type.—Continued.

RT Persei

	d	h
Dec.	11	2
	11	23
	12	19
	13	16
	14	12
	15	8
	16	5
	17	1
	17	22
	18	18
	19	14
	20	11
	21	7
	22	3
	23	0
	23	20
	24	17
	25	13
	26	9
	27	6
	28	2
	28	23
	29	19
	30	15
	31	12

λ Tauri

	d	h
Dec.	3	13
	7	12
	11	11
	15	9
	19	8
	23	7
	27	6
	31	5

RW Tauri

	d	h
Dec.	2	19
	5	13
	8	8
	11	2
	13	21
	16	15
	19	10
	22	4
	24	23
	27	17
	30	12

RW Persei

	d	h
Dec.	9	10
	22	14

RS Cephei

	d	h
Dec.	1	13
	13	23
	26	9

RW Geminorum

	d	h
Dec.	2	23
	5	20
	8	17
	11	13
	14	10
Dec.	17	7
	20	4
	23	0
	25	21
	28	18
	31	15

R Canis Maj.

	d	h
Dec.	1	17
	2	20
	3	23
	5	2
	6	6
	7	9
	8	12
	9	15
	10	19
	11	22
	13	1
	14	4
	15	8
	16	11
	17	14
	18	18
	19	21
	20	0
	22	3
	23	7
	24	10
	25	13
	26	16
	27	20
	28	23
	30	2
	31	5

Y Camelopardi

	d	h
Dec.	3	0
	6	7
	9	14
	12	22
	16	5
	19	12
	22	20
	26	3
	29	10

RR Puppis

	d	h
Dec.	5	6
	11	17
	18	3
	24	13
	32	0

V Puppis

	d	h
Dec.	1	6
	2	17
	4	4
	5	15
	7	2
	8	13
	10	0
	11	11
	12	21
Dec.	14	8
	15	19
	17	6
	18	17
	20	4
	21	15
	23	2
	24	13
	26	0
	27	10
	28	21
	30	8
	31	19

X Carinæ
Period 13^h

	d	h
Dec.	1	18
	2	20
	3	22
	5	0
	6	2
	7	4
	8	6
	9	8
	10	10
	11	12
	12	14
	13	16
	14	18
	15	20
	16	22
	18	0
	19	2
	20	4
	21	6
	22	8
	23	10
	24	12
	25	14
	26	16
	27	18
	28	20
	29	22
	31	0

S Cancri

	d	h
Dec.	1	15
	11	3
	20	14
	30	2

S Velorum

	d	h
Dec.	6	18
	12	16
	18	15
	24	13
	30	11

RR Velorum

	d	h
Dec.	2	12
	4	8
	6	5
	8	1
	9	22
Dec.	11	18
	13	15
	15	11
	17	8
	19	4
	21	1
	22	21
	24	18
	26	14
	28	11
	30	7

SS Carinae

	d	h
Dec.	3	7
	6	15
	9	22
	13	5
	16	12
	19	19
	23	3
	26	10
	29	17

Z Draconis

	d	h
Dec.	2	5
	3	14
	4	22
	6	7
	7	15
	9	0
	10	8
	11	17
	13	2
	14	10
	15	19
	17	3
	18	12
	19	21
	21	5
	22	14
	23	22
	25	7
	26	15
	28	0
	29	9
	30	17

δ Libræ

	d	h
Dec.	1	9
	3	17
	6	1
	8	9
	10	17
	13	0
	15	8
	17	16
	20	0
	22	8
	24	16
	27	0
	29	7
	31	15

U Coronæ

	d	h
Dec.	1	8
	4	19
	8	6
	11	17
	15	4
	18	15
	22	2
	25	12
	28	23

R Aræ

	d	h
Dec.	4	22
	9	8
	13	18
	18	4
	22	14
	27	1
	31	11

RR Draconis

	d	h
Dec.	2	19
	5	15
	8	11
	11	7
	14	3
	16	23
	19	19
	22	15
	25	11
	28	7
	31	3

RV Lyræ

	d	h
Dec.	1	4
	4	19
	8	9
	11	23
	15	14
	19	4
	22	18
	26	9
	29	23

U Sagittæ

	d	h
Dec.	1	9
	4	18
	8	3
	11	12
	14	21
	18	7
	21	16
	25	1
	28	10
	31	19

SY Cygni

	d	h
Dec.	2	3
	8	3
	14	3
	20	4
	26	4

Minima of Variable Stars of the Algol Type.—Continued.

WW Cygni		UW Cygni		RV Capricorni		VV Cygni		RZ Cassiop.	
	d h		d h		d h		d h		d h
Dec.	3 16	Dec.	13 7	Dec.	8 1	Dec.	26 17	Dec.	23 19
	7 0		16 18		11 7		28 5		25 0
	10 8		20 5		14 14		29 16		26 5
	13 15		23 16		17 20		31 4		27 9
	16 23		27 3		21 2	UZ Cygni			28 14
	20 7		30 13		24 8	Dec.	9 22		29 19
	23 14	W Delphini			27 14	RZ Cassiop.			30 25
	26 22	Dec.	4 4		31 20	Dec.	1 2	24.1907	
	30 5		9 0	VV Cygni			2 7	Monoc.	
SW Cygni			13 19	Dec.	1 15		3 12	Dec.	1 9
Dec.	4 22		18 14		3 2		4 16		3 7
	9 12		23 10		4 14		5 21		5 5
	14 2		28 5		6 1		7 2		7 2
	18 15	RR Delphini			7 13		8 7		9 0
	23 5	Dec.	2 6		9 0		9 11		10 22
	27 19		6 20		10 11		10 16		12 20
VW Cygni			11 10		11 23		11 21		14 18
Dec.	6 17		16 1		13 10		13 1		16 15
	15 3		20 15		14 22		14 6		18 13
	23 13		25 6		16 9		15 11		20 11
	31 23		29 20		17 21		16 15		22 9
UW Cygni					19 8		17 20		24 6
Dec.	2 23	RV Capricorni			20 20		19 1		26 4
	6 10	Dec.	1 13		22 7		20 5		28 2
	9 20		4 19		23 18		21 10		30 0
					25 6		22 15		31 21

Approximate Magnitudes of Variable Stars on Oct. 1, 1907.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
X Androm.	0	10.8	46	27	8.0 *i*	S Camelop.	5	30.2	+68	45	8.2
T Androm.		17.2	+26	26	12.5*d*	U Aurigae		35.6	+31	59	9.5*d*
T Cassiop.		17.8	+55	14	7.8 *i*	V Camelop.		49.4	+74	30	11 *i*
R Androm.		18.8	+38	1	10.5*d*	U Orionis		49.9	+20	10	11.0*d*
S Ceti		19.0	− 9	53	12.6 *i*	S Lyncis	6	35.9	+58	0	9.0 *i*
Y Cephei		31.3	+79	48	9.6 *i*	Y Draconis	9	31.1	+78	18	10.0*d*
U Cassiop.		40.8	+47	43	12.6*d*	R Urs. Maj.	10	37.6	+69	18	10.5 *i*
V Androm.		44.6	+35	6	10.8*d*	R Comae	11	59.1	+19	20	10.5*d*
RR Androm.		45.9	+33	50	10.0*d*	T Can.Ven.	12	25.2	+32	3	10.5*d*
W Cassiop.		49.0	+58	1	9.0*d*	T Urs. Maj.		31.8	+60	2	12.6*d*
U Androm.	1	9.8	+40	11	12.2*d*	RS Urs. Maj.		34.4	+59	2	12.6
S Piscium		12.4	+ 8	24	<13.8	S Urs. Maj.		39.6	+61	38	11.5*d*
S Cassiop.		12.3	+72	5	14.0	T Urs.Min.	13	32.6	+73	56	13.4 *i*
U Piscium		17.7	+12	21	<13.6	R Can. Ven.		44.6	+40	2	10.6 *i*
RU Androm.		32.8	+38	10	13.0	Z Bootis	14	1.7	+13	59	10.0*d*
Y Androm.		33.7	+38	50	<14	S Bootis		19.5	+54	16	10.3d
X Cassiop.		49.8	+58	46	12.0*d*	V Bootis		25.7	+39	18	11.4
U Persei		53.0	+54	20	11.0*d*	R Camelop.		25.1	+84	17	11.7*d*
R Arietis	2	10.4	+24	35	12.2*d*	R Bootis		32.8	+27	10	12.5
Z Cephei		12.8	+81	13	10.8 *i*	U Bootis		49.7	+18	6	12.5*d*
o Ceti		14.3	− 3	26	5.6 *i*	S Serpentis	15	17.0	+14	40	9.6*d*
S Persei		15.7	+58	8	9.8	S Coronae		17.3	+31	44	12.4*d*
RR Cephei		30.4	+80	42	11.0 *i*	RS Librae		18.5	−22	33	11.8*d*
R Trianguli		31.0	+33	50	9.9*d*	RU Librae		27.7	−14	59	9.6*d*
Y Persei	3	20.9	+43	50	9.4*d*	X Librae		30.4	−20	50	11.4 *i*
R Persei		23 7	+35	20	10.4 *i*	W Librae		32.2	−15	51	10.5 *i*
T Camelop.	4	30.4	+65	57	13.0*d*	S Urs.Min.		33.4	+78	58	9.2*d*
X Camelop.		32.6	+74	56	13.0	U Librae		36.2	−20	52	10.2 *i*
R Aurigae	5	9.2	+53	28	10.8 *i*	Z Librae		40.7	−20	49	13.8*d*

Approximate Magnitudes of Variable Stars on Oct. 1, 1907—Con.

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
R Coronae	15 44.4	+28 28	6.0	Z Sagittarii	19 13.8	−21 7	<1.35
X Coronae	45.2	+36 35	13.0	RY Sagittarii	10.0	−33 42	7.0
R Serpentis	46.1	+15 26	9.0*d*	TZ Cygni	13.4	+50 0	10.8 *i*
V Coronæ	46.0	+39 52	11.6*d*	U Lyrae	16.6	+37 42	10.5 *i*
— Coronæ			12.8	T Sagittae	17.2	+17 28	9.0
RR Librae	50.6	−18 1	14.0*d*	TY Cygni	29.8	+28 6	8.4 *i*
RZ Scorpii	58.6	−23 50	13.6*d*	R Cygni	34.1	+49 58	11.8*d*
R Herculis	16 1.7	+18 38	13.6*d*	RV Aquilae	35.9	+ 9 42	<11.8
RR Herculis	1.5	+50 46	9.7*d*	RT Aquilae	33.3	+11 30	11.6*d*
U Serpentis	2.5	+10 12	9.2*d*	RT Cygni	40.8	+48 32	12.8*d*
R Scorpii	11.7	−22 42	<14	TU Cygni	43.3	+48 49	13.3*d*
RU Herculis	6.0	+25 20	12.4*d*	X Aquilae	46.5	+ 4 13	11.4 *i*
S Scorpii	11.7	−22 39	12.8*d*	χ Cygni	46.7	+32 40	12.0*d*
W Coronae	11.8	+38 3	14.0*d*	RR Aquilae	52.4	− 2 11	13.6*d*
W Ophiuchi	16.0	− 7 28	9.4 *i*	RS Aquilae	53.7	− 8 9	12.0 *i*
V Ophiuchi	21.2	−12 12	10.8	Z Cygni	58.6	+49 46	13.5*d*
U Herculis	21.4	+19 7	9.8*d*	S Cygni	20 3.4	+57 42	<14
SS Herculis	28.0	+ 7 3	11.5*d*	SY Aquilae	2.3	+12 39	12 5
S Ophiuchi	28.5	−16 57	14.0*d*	R Capricorni	5.7	−14 34	13.8
T Ophiuchi	28.0	−15 55	13.8*d*	S Aquilae	7.0	+15 19	9.8
W Herculis	31.7	+37 32	11.8 *i*	RU Aquilae	8.0	+12 42	10.8 *i*
R Draconis	32.4	+66 58	10.2*d*	W Capric.	8.6	−22 17	13.5
RR Ophiuchi	43.2	−19 17	8.0	Z Aquilae	9.8	− 6 27	11.9 i
S Herculis	47.4	+15 7	11.2 *i*	RS Cygni	9.8	+38 28	8.8
RV Herculis	56.8	+31 22	8.3 *i*	R Delphini	10.1	+ 8 47	9.8*d*
R Ophiuchi	17 2.0	−15 58	13.2 *i*	RT Capricorni	11.3	−21 38	7.4
RT Herculis	6.8	+27 11	<13.5	SX Cygni	11.6	+30 46	12.4*d*
Z Ophiuchi	14.6	+ 1 37	7.6 *i*	WX Cygni	14.8	+37 8	11.6*d*
RS Herculis	17.5	+23 1	9.7*d*	V Sagittae	15.8	+20 47	12.5
RU Ophiuchi	28.1	+29 30	13.0	U Cygni	16.5	+47 35	10.0*d*
RS Ophiuchi	44.8	− 6 40	11.2*d*	RW Cygni	25.2	+39 39	8.8
RT Ophiuchi	51.8	+11 11	12.4*d*	RU Capric.	26.7	−22 2	9.4 *i*
T Draconis	54.8	+58 14	10.2 *i*	Z Delphini	28.1	+17 7	<13.5
— Draconis	54.8	+58 14	12.0*d*	ST Cygni	29.9	+54 38	9.8
RY Herculis	55.4	+19 29	13.4*d*	Y Delphini	36.9	+11 31	13.0
V Draconis	56.3	+54 53	13.7*d*	S Delphini	38.5	+16 44	9.6 *i*
T Herculis	18 5.3	+31 0	13.2*d*	V Cygni	38.1	+47 47	10.8 *i*
W Draconis	5.4	+65 56	12.0*d*	Y Aquarii	39.2	− 5 12	13.0 *i*
X Draconis	6.8	+66 8	<13.5	U Capricorni	42.6	−15 9	12.5*d*
RY Ophiuchi	11.6	+ 3 40	9.6 i	T Delphini	40.7	+16 2	13.2*d*
W Lyrae	11.5	+36 38	9.4*d*	V Aquarii	41.8	+ 2 4	8.6*d*
T Serpentis	23.9	+ 6 14	11.8 *i*	W Aquarii	41.2	− 4 27	10.6*d*
RZ Herculis	32.7	+25 58	10.4*d*	V Delphini	43.2	+18 58	<14
X Ophiuchi	33.6	+ 8 44	8.8*d*	T Aquarii	44.7	− 5 31	13.0*d*
RY Lyrae	41.2	+34 34	<14	RZ Cygni	48.5	+46 59	10.4*d*
RW Lyrae	42.1	+43 32	10.0	X Delphini	50.3	+17 16	13.0
Z Lyrae	56.0	+34 49	10.8 *i*	UX Cygni	50.9	+30 2	10.4 *i*
RX Lyrae	50.4	+32 42	<14	R Vulpeculae	59.9	+23 26	8.4*d*
ST Sagittarii	55.9	−12 54	<13.8	TW Cygni	21 1.8	+29 0	<13.6
RT Lyrae	57.8	+37 22	<14	V Capric.	1.8	−24 19	11.6
R Aquilae	19 1.6	+ 8 5	9.0 *i*	X Capric.	2.8	−21 45	11.4
V Lyrae	5.2	+29 30	<13.6	X Cephei	3.6	+82 40	14.0*d*
RX Sagittarii	8.7	−18 59	<12	RS Aquarii	5.8	− 4 27	11.2
RW Sagittarii	8.1	−19 2	9.8*d*	Z Capricorni	5.0	−16 35	10.2
S Lyrae	9.1	+25 50	12.0 *i*	R Equulei	8.4	+12 23	13.6
RS Lyrae	9.3	+33 15	13.8*d*	T Cephei	8.2	+68 5	8.6*d*
RU Lyrae	9.1	+41 8	10.2 *i*	RR Aquarii	9.8	− 3 19	10.5
U Draconis	9.9	+67 7	12.5*d*	X Pegasi	16.3	+14 2	12.6
W Aquilae	10.0	− 7 13	13.0	T Capricorni	16.5	−15 35	<13
T Sagittarii	10.5	−17 9	10.9*d*	Y Capricorni	28.9	−14 25	13.6
R Sagittarii	10.8	−19 29	7.5 *i*	S Cephei	36.5	+78 10	9.8
S Sagittarii	13.6	−19 12	11.0*d*	RR Pegasi	40.0	+24 33	9.3 *i*

Approximate Magnitudes of Variable Stars on Oct. 1, 1907.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
V Pegasi	21	56.0	+ 5	38	11.5	R Pegasi	23	1.6	+10	0	8.2 *i*
U Aquarii		57.9	−17	6	19.6	V Cassiop.		7.4	+59	8	8.0 i
RT Pegasi		59.8	+34	38	11.6*d*	W Pegasi		14.8	+25	44	10.4 *i*
T Pegasi	22	4.0	+12	3	11.0 *i*	S Pegasi		15.5	+ 8	22	12.4*d*
Y Pegasi		6.8	+13	52	7.4*d*	R Aquarii		38.6	−15	50	8.5*d*
RS Pegasi		7.4	+14	4	11.4*d*	Z Cassiop.		39.7	+56	2	<13.4
X Aquarii		13.2	−21	24	11.9	RR Casiop.		50.7	+53	8	10.4
RT Aquarii		17.7	−22	34	11.6*d*	Z Aquarii		47.1	−16	25	7.5
S Lacertae		24.6	+39	48	8.9 *i*	V Ceti		52.8	− 9	31	<13.4
R Lacertae		38.8	+41	51	8.9 *i*	R Cassiop.		53.3	+50	50	7.3*d*
S Aquarii		51.8	−20	53	10.0*d*	Z Pegasi		55.0	+25	21	13.0
RW Pegasi		59.2	+14	46	11.6*d*	W Ceti		57.0	−15	14	7.0
						Y Cassiop.		58.2	+55	7	<14

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin, Vassar College and Harvard Observatories.

GENERAL NOTES.

E. S. Martin of Wilmington, N. C., kindly sends us information about the appearance of a meteorite that was seen and heard in Pennsylvania, New York and northern Ohio, on October 2. The account from Hamsburg is as follows:— "With the roar like that of a cannon, a big meteorite fell in the mountains back of Elizabeth last night, setting fire to the forest and frightening hundreds of people. The roar and following report as the meteorite struck the Earth (or burst in air) was heard all over the northern end of Dauphin county.

From various points in southern New York state, northern Pennsylvania and northern Ohio, came reports of a "ball of fire" being seen about the time of the falling of the meteorite. Another report from Dubois, Pa., spoke of the fall of the meteorite as dazzling and terrifying, large masses falling at three different times."

If any of our readers can give, or procure a trustworthy account of the fall of this meteorite, it certainly ought to be done for the sake of a record in some scientific journal.

Mrs. Todd's Address. By the invitation of the Geographical Society of Lima, Mrs. Mabel Louise Todd gave an address before that body on September 12th, at the rooms of the Society in Lima, on the Ainus or aborigines of northern Japan, among which she made extensive travels in 1896 when the Amherst Eclipse Expedition visited that region.

The Moon's Rotation. A correspondent asks if the Moon's rotation is not dependent on its revolution.

Certainly not. The two motions are entirely independent of each other. The fact that the rotation and revolution nearly coincide in time does not prove that they are interdependent.

Cause of Lunar Rotation. The same correspondent asks if there is not some constant outside force that controls the rotation of the Moon.

The supposition is that the querist means to ask if there is not some constant, outside force that started the rotation of the Moon on its axis and still keeps up its motion.

This question should be divided into two parts, and answer given to each separately.

1. How was the rotation of the Moon on its axis started in the beginning?

Astronomy has no certain answer for this query. Theory offers suggestions to account for it, but no one can tell certainly what the cause was. If the Moon and the Earth were once united in one nebulous mass in rotation, it is easy to see how such rotation of the lunar part could take place when abandoned by the greater Earth or parent nebula according to the nebular hypothesis. That view of the origin of lunar rotation is favored in late text-books on astronomy.

2. How is the Moon's motion on its axis sustained or controlled?

In regard to the Moon's motion on its axis, it may be said that its motion seems to be under constraint by some outside force. It may be due as some physicists think, to tidal relations with the Earth formerly, and later to the fact that the Moon's center of mass is not at the center of volume, and, because of this, the Earth's attraction constantly keeps nearly the same face of the Moon towards us. If this be the true explanation of the relation of the two bodies, it would not make the libration of the Moon in longitude either harder or easier to understand so far as we now know.

Burnham's Double Stars. A subscriber asks for the best work on Double Stars, for reference.

The latest and most complete work on double stars is by S. W. Burnham of Yerkes Observatory, Williams Bay, Wis. It is published in two large volumes by the Carnegie Institution, Washington D. C. Price $14.

Variable Stars. We have another inquiry about Variable Stars: "What is the best catalogue of variable stars ?"

Father Hagen's Variable Star Atlas is undoubtedly the most complete work on this branch of astronomy at the present time.

The great thing in the way of getting it, is its cost. The price of the entire work is said to be between $75 and $100. One could wish that so useful a work could be afforded for less money. This is true because the branch of variable star work is one in which many amateurs can engage profitably, and such a reference book would be more generally useful.

S. C. Chandler's variable star catalogues are very generally used.

Catalogue of Red Stars also has been sought for by one interested in that line of work.

There are several catalogues of the red stars easily within the reach of those who desire information of this kind.

Dreyer's Catalogue of 1882 which contains the mean places of 521 red stars, chiefly from Schjellerup's Catalogue, made at Dunsink, Dublin, Ireland, part IV, p. 77.

Chambers Catalogue of red stars will be found in his Descriptive Astronomy, the edition of 1877, p. 588.

The Birmingham Catalogue of red stars, 1877, will be found in Dublin Transactions XXVI, No. 7.

Schjellerup's Second Catalogue of red stars, 1874, Vjh. IX. 252. Leipzig.

We are not sure that all of these catalogues are still in print. The scientific book. Sellers of Chicago or New York probably, could give any information about them desired.

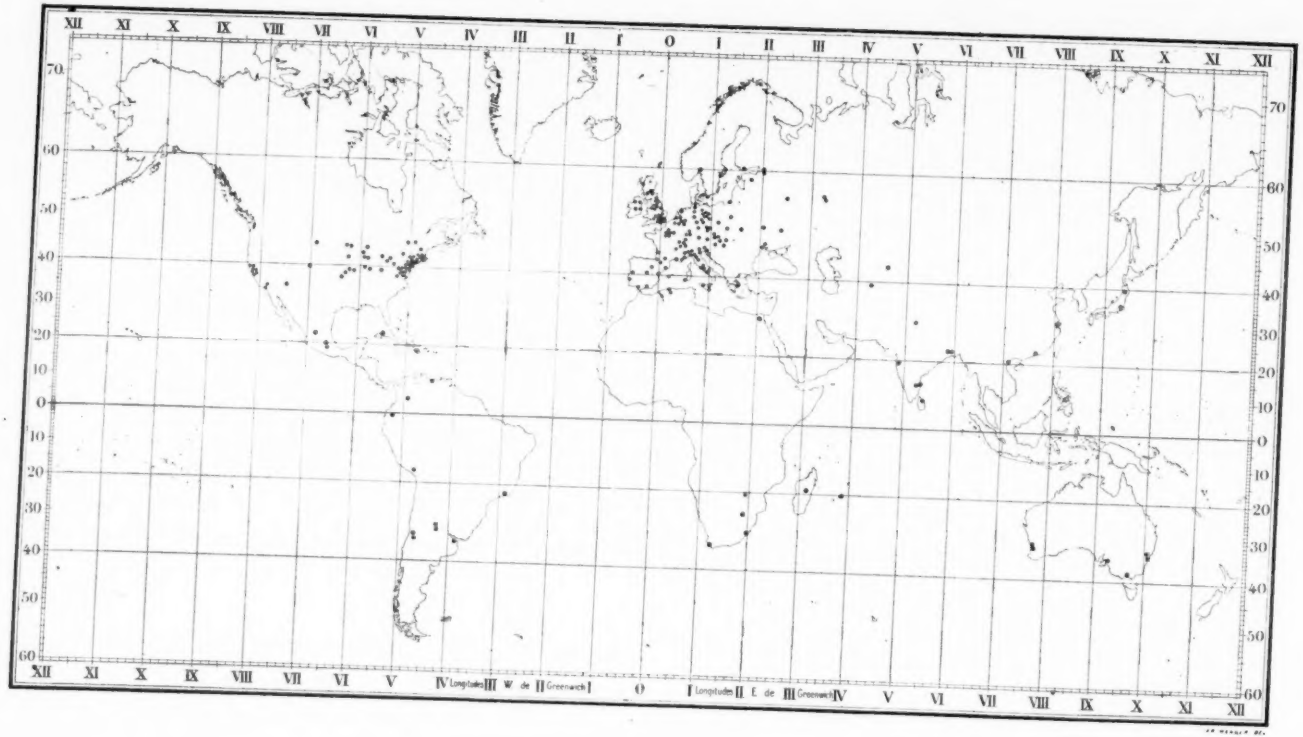
John E. Mellish, Cottage Grove, Wis., writes August 19, that while sweeping for comets on August 12, he found what appeared to him to be a meteor trail five degrees south of η Ursæ Majoris; the trail was eight degrees long and two minutes wide, and it extended northwest and southeast. It was moving northward one degree per hour. It was first seen at 9:30 in the evening, and it was cloud-covered at 1:30 and the sky was cloudy on the following evening.

This object could not have been a meteor trail. We are not aware that the place given is that of any known comet. Possibly some other observer may have seen the same object.

What are the Canals of Mars. The leading article in *Knowledge* (English) for September is on the physical interpretation of the Canals of Mars. The following is a careful and a thoughtful summary in the words of another:

"It is too soon yet to say whether the opportunities afforded by the opposition of Mars have added anything substantial to the valuable results which Mr. Lowell and his astronomical assistants have so zealously accumulated, but it is not likely that any one fact will be discovered which will settle once and for all whether the markings on Mars are or are not of a kind to justify the speculation that they are canals. The question has been debated in KNOWLEDGE during the last seven years, and the most eminent of American astronomers, Professor Simon Newcomb, has now come forward with a careful analysis of the methods which have been adopted in observing the Martian "canals." He adds a suggestion as to certain experiments in examining lines and markings which observers of the canals ought to make. Professor Newcomb's attitude, as summarized in KNOWLEDGE, may be summed up as follows: (1) He does not question the fact that the observers have seen the markings, even the fainter markings, which they attribute to the surface of Mars. But (2) he thinks we are not yet justified in asserting that the lines have the appearance in fact which the observers have given to them when re-drawing them on a map. Again, having made elaborate calculations as to the width which the canals would have to be in order to be visible in the best telescope which can be turned on them, Professor Newcomb finds that the system of 398 canals named and catalogued in the "Annals" of Lowell Observatory has an apparent area of 33,000,000 square miles. The actual surface of Mars is about 55,000,000 square miles. Therefore the canals occupy probably at least half the area of the planet. This does not necessarily disprove their possibility, but it does indicate an enormous complexity of canals on a disk that looks about the size of a sixpence; and it would not be surprising, therefore, if mistakes had occurred and misinterpretations had been made in charting them. It should be added in elucidation of the foregoing figures that Professor Newcomb estimates that the apparent breadth of a Martian canal, if it is to be perceptible through a telescope, would be forty miles. Its average length is 1,500 miles."

Stroobant's Astronomical Observatories and Astronomers. This useful hand book of 316 pages tabulates the astronomical observatories and the astronomers of the world, in a way to make such matter easy of reference and quite complete in general detail. The author, P. Stroobant is an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astronomer in the Royal Observatory of Belgium at Uccle, and his particular line of work there is that of the meridian service. He is also professor in the University of Brussels.

In giving data pertaining to the observatories, the geographical position, the personel, the instruments, the kinds of astronomical work pursued, a list of publications is usually named with each. This matter covers 252 pages, and is arranged so that the names of the places of the observatories come in alphabetical order, and therefore the data of any one Observatory are very easily found.

Next is given a list of the principal astronomical societies of the world with a few facts pertaining to the history of it. Also, a list of thirteen astronomical magazines with data such as price, name of editor, date of founding; and following that an alphabetical list of astronomers, a list of places in particular countries where observatories are located, and a list of societies and magazines that are found in countries that are particularly named.

Another interesting feature is found near the end of the volume, and that is a double paged map covering the surface of the Earth from 60° south latitude to 70° north latitude showing the locality of all the principal observatories of the world. This map, in reduced form, we have copied, so that our readers at a glance, might see where the large part of astronomical work in the world is now being done.

An Integral Elegantly Reduced by Hyperbolic Functions.

The integral $I = \int_0^{\phi} \frac{d\phi}{\sqrt{(1 - k^2 \sin \phi^2)(1 - c^2 \sin \phi^2)}}$

may by means of hyperbolic functions simply and elegantly be reduced to an Elliptic I of the first kind.

Assuming $k > c$, both fractional of course, my deducement is as follows:

Making $\quad k \sin \phi = \text{hytang } \theta$

results: $\quad c \sin \phi = \frac{c}{k} \text{ hytang } \theta$

$$\sin \phi = \frac{1}{k} \text{ hytg } \theta, \quad d\phi = \frac{1}{k \cos \phi^2} \cdot \frac{d\theta}{\text{hycos } \theta^2}$$

consequently for: $\quad \cos \phi = \sqrt{1 - \frac{1}{k^2} \text{ hytg } \theta^2}$

$$d\phi = \frac{d\theta}{\text{hycos } \theta \sqrt{k^2 \text{ hycos } \theta^2 - \text{hysin } \theta^2}}$$

The substitution results:

$$I = \int \frac{d\theta}{\sqrt{1 - \text{hytg } \theta^2} \cdot \sqrt{1 - \frac{c^2}{k^2} \text{ hytg } \theta^2} \cdot \text{ hycos } \theta \cdot \sqrt{k^2 \text{ hycos } \theta^2 - \text{hysin } \theta^2}}$$

$$= \int \frac{\text{hycos}\,\theta d\theta}{\sqrt{(k^2\,\text{hycos}\,\theta - \text{hysin}\,\theta^2)(\text{hycos}\,\theta^2 - \frac{c^2}{k^2}\text{hysin}\,\theta^2)}}$$

$$= \int \frac{\text{hycos}\,\theta d\theta}{\sqrt{(k^2 - (1-k^2)\,\text{hysin}\,\theta^2)\,(1 + \frac{k^2-c^2}{k^2}\,\text{hysin}\,\theta^2)}}$$

$$= \frac{1}{k} \int \frac{\text{hycos}\,\theta d\theta}{\sqrt{(1 - \frac{1-k^2}{k^2}\,\text{hysin}\,\theta^2)\,(1 + \frac{k^2-c^2}{k^2}\,\text{hysin}\,\theta^2)}}$$

or introducing a new variable:

$$x = \text{hysin}\,\theta$$

$$I = \frac{1}{k} \int \frac{dx}{\sqrt{(1 - \frac{1-k^2}{k^2}\,x^2)\,(1 + \frac{k^2-c^2}{k^2}\,x^2)}} \qquad (1)$$

which in the generally known way may be transformed to the Legendre Normal

$$\frac{1-k^2}{k^2}\,x^2 = \cos\mu^2; \qquad dx = \frac{-k}{\sqrt{1-k^2}}\,\sin\mu\,d\mu\ ^*$$

results from (1):

$$I = \frac{1}{\sqrt{1-k^2}} \int \frac{\sin\mu\,.\,d\mu}{\sqrt{(1-\cos\mu^2)\,(1 + \frac{k^2-c^2}{1-k^2}\,\cos\mu^2)}}$$

$$= \frac{1}{\sqrt{1-k^2}} \int \frac{d\mu}{\sqrt{1 - \frac{k^2-c^2}{1-c^2}\,\sin\mu^2}}$$

for the limit of the integrative is:

$$\cos\mu = \frac{x\sqrt{1-k^2}}{k},$$

consequently

$$\text{tang}\,\frac{\mu^2}{2} = \frac{k - x\sqrt{1-k^2}}{k + x\sqrt{1-k^2}}$$

For any hyperbolic argument θ exists an arc α in the first quadrant, so as to make: $\text{hytang}\,\theta = \sin\alpha$, $\text{tang}\,\alpha = \text{hysin}\,\theta$ †

Consequently:

for $\text{hytg}\,\theta = \sin\alpha = k\sin\phi$

$$x = \text{hysin}\,\theta = \text{tang}\,\alpha,$$

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* The minus sign we may drop at once. Integral I has the $\pm$ to it for its very nature.

† The first publication of these hyperbolically conjugated arcs I made in "Oesterreichsache Wachenschrift für des Offentliches Bandienst" year 1904 p. 434, Foot note 2.

or

$$\text{tang}\,\frac{\mu^2}{2} = \frac{k - \text{tg}\,\alpha\,\sqrt{1-k^2}}{k + \text{tg}\,\alpha\,\sqrt{1-k^2}}$$

and the final result:

For $k = \sin\kappa, \qquad k\sin\phi = \sin\alpha$

$$\text{tang}\,\frac{\mu}{2} = \sqrt{\frac{\sin(\kappa-\alpha)}{\sin(\kappa+\alpha)}}$$

$$\int_0^{\phi} \frac{d\phi}{\sqrt{(1-k^2\sin\phi^2)(1-c^2\sin\phi^2)}} = \frac{1}{\sqrt{1-c^2}} \int^{\mu} \frac{d\mu}{\sqrt{1-\frac{k^2-c^2}{1-c^2}\sin^2\mu}}$$

FRANCIS RUST.

Allegheny, Pa.

Radiant Point for Meteors Connected with Comet *d* 1907.— In *A. N.* 4198 Mr. H. H. Kritzinger of Berlin shows that on July 27 comet *d* 1907 was in heliocentric latitude −3°.9 and at a distance of only 0.068 from the Earth's orbit. If this comet were accompanied by an immense swarm of meteors, as is true of certain other comets, the Earth might pass through the outer portion of the swarm at the time of its nearest approach to the comet's path, i. e. about September 12. Mr. Kritzinger calculates the position of the resulting meteor radiant as R. A. $23^h\ 08^m$, Dec. + 3°. According to Schmidt (*A. N.* 1756) there is a permanent meteor radiant agreeing with this in position.

Distances of the Fixed Stars. The issue of *Science*, July 26, pp. 118-119 gives a brief article by J. M. Schaeberle, director of Detroit Observatory, Ann Arbor, Michigan, in which he says, for some years he has been at work on the physical structure of the sidereal system. We quote a few of the paragraphs from it as follows:—

"The results so far obtained are novel, since they indicate that the structure is radial, in other words the stars and nebulas of our system are moving either directly towards or directly away from our Sun; the observed deviations from radial motion being attributed to the unsymmetrical distribution of the attracting masses, and also to the presence of bodies having a secondary origin.

"The indications also point to the conclusion that as seen from our Sun, a vast majority of the stars and nebulas are confined to a region whose radial depth is much less than the distance of this region from our Sun. Since bodies so situated may be comparatively near to us and still have various radial velocities without causing sensible changes in the configuration of the heavens, the seemingly unchanging aspect of the Milky Way*

* Whether the theory is in agreement with the actual facts or not, I demonstrate that the inclination of the plane (?) of a Milky Way to the plane of the Sun's equator is a necessary consequence of such a structure.

and other celestial regions is explained without the necessity of assigning such great distances (and consequently such great masses) to the bodies of our system.

"Considering the still undetermined constants entering into the problem, and the lack of a rigorous method for making direct measures, it surely is no exaggeration to say that a trustworthy value of a star's parallax has not yet been obtained.

"The award of the Boyden Premium by the Franklin Institute to Dr. Heyl is doubtless a well-deserved honor, but when one reads in *Science* for June 28, 1907, on page 1013, that a definite result is based upon the wholly unproved claim that "the distance of Algol is no less than forty light years" it seems desirable to emphasize the fact that in the present state of our knowledge the approximate distance of any particular fixed star must still be regarded as an unknown quantity."

These statements from Schaeberle will surprise and interest astronomers having practical experience in the study of stellar parallax.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with January 1906, the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers issued previous to the change of price, January 1906, are still on sale at the old prices, $2.50 and 30 cents respectively.

WM. W. PAYNE,
Northfield, Minn., U. S A.